TRIUMF - RESEARCH PROPOSAL	Experiment no. E1112	Sheet 1 of 18

Title of proposed experiment

Mass measurement of neutron-rich isotopes around N =34

Name of group

TITAN

Spokesperson for group

Hervé Savajols and Jens Dilling

Email address

Savajols@triumf.ca and JDilling@triumf,ca

Members of group (name, institution, status)

(For each member, include percentage of research time to be devoted to this experiment over the time frame of the experiment)

H. Savajols	GANIL/TRIUMF	Scientist	50 %
J. Dilling	TRIUMF	Scientist	50 %
P. Delheij	TRIUMF	Scientist	50 %
W. Mittig	GANIL	Scientist	20 %
P. Roussel-Chomaz	GANIL	Scientist	20 %
A.C.C. Villari	GANIL	Scientist	20 %
A. Chbihi	GANIL	Scientist	10 %
A. Gillibert	CEA/Saclay	Scientist	10 %
N. Orr	LPC/Caen	Scientist	10 %
M. Chartier	Univ. Liverpool	Scientist	10 %
G. Ball	TRIUMF	Scientist	10 %
G. Hackman	TRIUMF	Scientist	10 %
I. Tanihata	TRIUMF	Scientist	10 %
C. Ravuri	TRIUMF/SFU	Research Associate	10 %
R. Kanungo	TRIUMF	Research Associate	10 %
F.Sarazin	Colorado School of Mines	Professor	10 %
G. Gwinner	U. of Manitoba	Professor	10 %
A. Allaoua	GANIL	Phd Student	50 %
L.Gaudefroy	GANIL	Post-Doc	10 %
M.Smith	UBC	Student	50 %
M.Brodeur	UBC	Student	50 %
C.Champagne	McGill	Student	50 %
V. Ryjkov	TRIUMF	Post-Doc	50 %

20

Beam time requested: 20 shifts

12-hr shifts **Beam line/channel** **Polarized primary beam?**

Date ready:

date

Completion date:

date

SUMMARY	Sheet 2 of 18

Do not exceed one page.

The aim of the proposed experiment is to carry out mass-measurements of neutron-rich $^{49,50,51,52,53}K$, $^{51,52,53}Ca$ and $^{52,53}Sc$ isotopes using TITAN. This will constrain nuclear structure models which predict appearance/disappearance of magic numbers at N = 32-34. The Z = 20 proton shell closed, and thus the neutron-rich calcium isotopes provide a unique opportunity to delineate neutron shell structure above N = 28; especially, the information on the ordering and on the location of the $p_{3/2}$, $p_{1/2}$ and $f_{5/2}$ single-particle orbitals, that are sensitive to the binding energy. In this TITAN experiment, five masses will be measured for the first time and 6 others will be improved, and will provide additional accurate reference-masses, that are indispensable for calibrating data of lesser precision in that region.

These measurements are complementary to the mass-measurement programs using time-of-flight/rigidity analysis performed at the GANIL-SPEG facility [1], and more recently at MSU-NSCL's S800 facility [2].

Experimental device: TITAN

BEAM and SUPPORT REQUIREMENTS	

Experimental area

TITAN

Primary beam and target (energy, energy spread, intensity, pulse characteristics, emittance)

Secondary channel

Secondary beam (particle type, momentum range, momentum bite, solid angle, spot size, emittance, intensity, beam purity, target, special characteristics)

TRIUMF SUPPORT:
Summarize all equipment and technical support to be provided by TRIUMF. If new equipment is required, provide cost estimates.

NOTE: Technical Review Forms must also be provided before allocation of beam time.

NON-TRIUMF SUPPORT:
Summarize the expected sources of funding for the experiment.
Identify major capital items and their costs that will be provided from these funds.

Summarize possible hazards associated with the experimental apparatus, precautions to be taken, and other matters that should be brought to the notice of the Safety Officer. Details must be provided separately in a safety report to be prepared by the spokesperson under the guidance of the Safety Report Guide available from the Science Division Office.

The TITAN facility will operate with low levels of radioactive beam. Radioactive hazards are not envisaged during the experimental runs. When the beam line has to be opened standard ISAC procedure will be followed to check for contamination. Other potential hazards areas include the charge breeding EBIT (X-rays) and the high voltage operation of the RFQ and the EBIT. All three areas will have been safety commissioned by the time the experiments will be carried out. Local shielding for the x-rays and a lock-out procedure for the HV Faraday cages will be in place.

Abstract

The aim of the proposed experiment is to carry out mass-measurements of neutron-rich ^{49,50,51,52,53}K, ^{51,52,53}Ca and ^{52,53}Sc isotopes using TITAN. This will constrain nuclear structure models which predict appearance/disappearance of magic numbers at N = 32-34. The Z = 20 proton shell closed, and thus the neutron-rich calcium isotopes provide a unique opportunity to delineate neutron shell structure above N = 28; especially, the information on the ordering and on the location of the $p_{3/2}$, $p_{1/2}$ and $f_{5/2}$ single-particle orbitals, that are sensitive to the binding energy. In this TITAN experiment, five masses will be measured for the first time and 6 others will be improved, and will provide additional accurate reference-masses, that are indispensable for calibrating data of lesser precision in that region. These measurements are complementary to the mass-measurement programs using time-of-flight/rigidity analysis performed at the GANIL-SPEG facility [1], and more recently at MSU-NSCL's S800 facility [2].

1. Motivations

Nuclear structure changes are theoretically predicted in neutron-rich nuclei [3]. Deformations, shape coexistence or variations in the spin-orbit strength as a function of the neutron to proton ratio could provoke the modification of magic numbers. Such behaviour has consequences in other domains, as seen for example in nucleo-synthesis, where a quenching of shell effects, and consequently of spin orbit splitting, can provide for a better agreement between model calculations and observed abundances [4]. Experimentally, nuclear binding energies are very sensitive to the existence of shell structure and may provide clear signatures of new shell closures [5]. For instance, mass measurements [6] following Coulomb excitation studies [7] and theoretical calculations [8] have already given clear evidence of the disappearance of the N=20 magic gap, as in, $^{32}Mg_{20}$ due to the intruder deformed configuration coming from the next oscillator shell. A similar disappearance of the N=28 magic number was evidenced from the determination of the lifetime [9] and deformation [10] of $^{44}S_{16}$, as well as mass measurement [11] of neutron rich nuclei around N=28 for Cl, S and P isotopes. Both the shell model and relativistic mean field calculations showed that deformed prolate ground state configurations, associated with shape coexistence, are necessary to account for the experimental results.

In the *fp* shell, the relative energies of the $p_{3/2}$, $p_{1/2}$ and $f_{5/2}$ orbits and their evolution as a function of valence proton numbers determine where sub shell closures takes place. Most of the shell model effective interactions predict a sub shell closure at N = 32 for Ca nuclei. Confirmation of this subshell gap has already been achieved that are based on the results of beta-decay measurements, B(E2) transition strengths, and the high-spin structure of the even-even ^{56}Cr and ^{54}Ti nuclei. Recently, a new effective interaction, labeled GXPF1, for use in the full *pf* shell was proposed by Homma et al [12]. Shell-model calculations with this interaction reproduced very well the systematic variation in the energy of the fist excited 2+ states for the Cr nuclei around N = 32, as well as that of the high-spin states in the even-even Ti isotopes. An intriguing result of these calculations is the expectation that a sizable energy gap should occur in the neutron single-particle energies between the $p_{1/2}$ and $f_{7/2}$ orbitals, leading to the development of N=34 as a new magic number for neutron-rich nuclei (as shown in Figure 2). The shell-structure evolution is expected to be reflected in mass measurements.

Furthermore, the masses of most of these neutron-rich nuclei have never been measured or have been obtained with large uncertainties [12] (ΔM = 700 keV for ^{52}Ca, AME03). Presently, TRIUMF ISAC facility offers a unique opportunity to produce very neutron-rich nuclei of interest. Very recently, E1064 experiment has successfully measured the low-energy quantum structure of neutron-rich ^{51,52,53}Ca isotopes populated following the β decay of ^{51,52,53}K, using the 8Pi setup.

With this background we propose to measure masses of neutron rich ^{49,50,51,5253}K, ^{51,52,53}Ca and ^{52,53}Sc in that region, that would constraint on nuclear-structure models.

The new data will also provide additional accurate reference masses indispensable for calibrating the data of lesser precision in that region obtained recently at NSCL [2] and scheduled at GANIL [1].

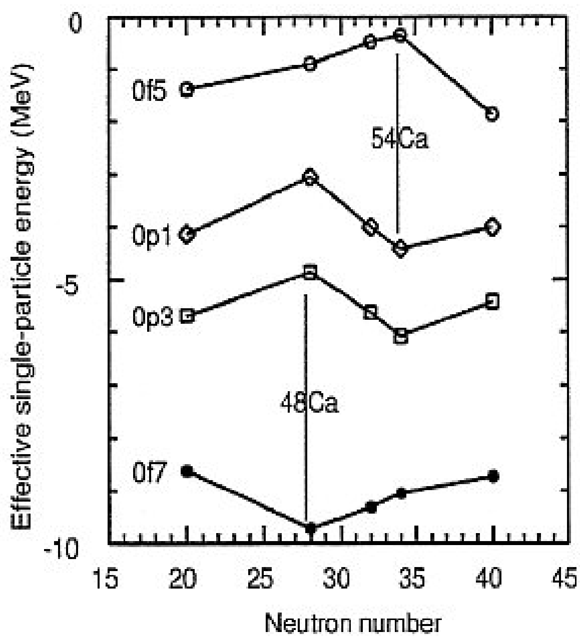

Fig. 1. Effective single particle energies from the GXPF1 interaction.

2. The proposed experiment

The radioactive ion will be produced by an ionization and isotope separation following the bombardment of thick production targets with high intense of 500 MeV protons from TRIUMF's main cyclotron. With the recent development of suitable ion sources (e.g. surface and the TRIUMF Resonant Laser Ion Sources (TRILIS)) and the capability of handling proton beam intensities on target of up to 100 μA, it would be possible to carry out accurate mass measurement of $^{49\text{-}53}$K, $^{51\text{-}53}$Ca and $^{52\text{-}53}$Sc (see figure 2).

Figure 3 shows yield measurement of K, Ca, Sc, Ti and V elements obtained last year with 55 µA of proton beam bombarding a high power Ta target. During this run, surface ion source was used. In addition, the use of TRILIS ion source will enhance the Ca yields by a factor 5, as tested recently. This improvement in beam-intensity combined with high proton-intensity, of the order of 85 µA (gain of about a factor 2), is expected to give a significant improvement in the production rate for those isotopes.

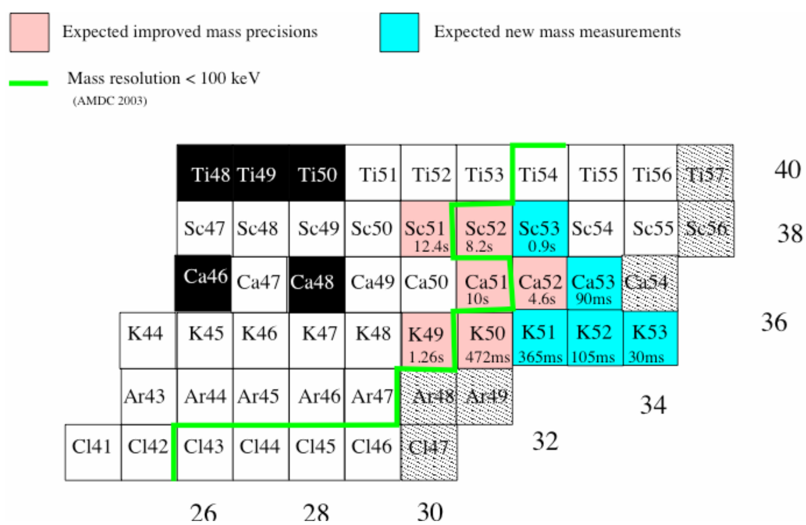

Fig 2. Expected results of mass measurements, including unknown masses and nuclei where masses should be improved significantly.

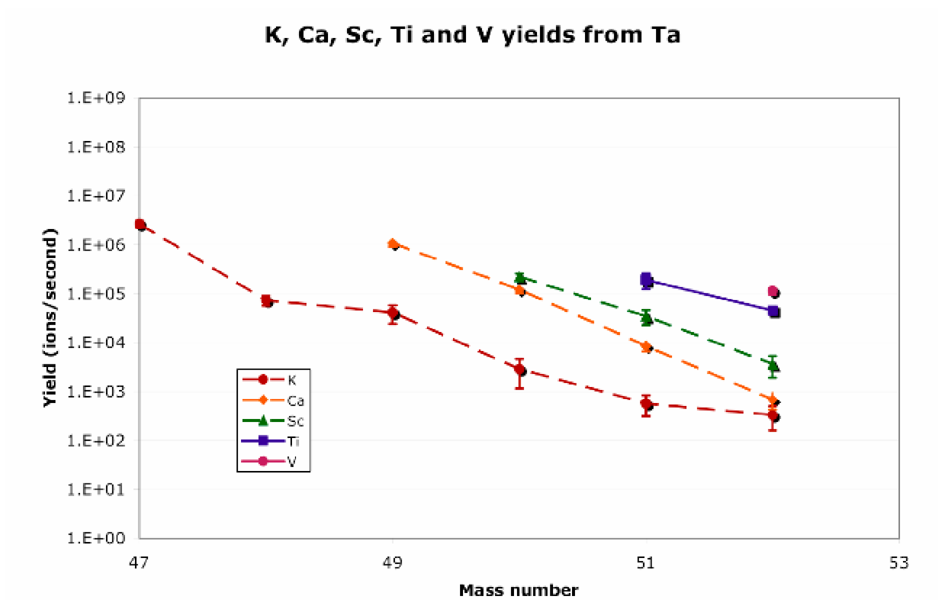

Fig 3. Yield measurement obtained in 2005 with a beam intensity of 55 µA on high power tantalum target.

Table 1 summarizes the list of isotopes to be measured at TITAN; Given is the isotope, half-life, present mass uncertainty from [AME03], uncertainty that can be achieved with TITAN (assuming 3000 measured ions). In addition the production method, yields are given.

Isotope	***Half-live***	***Present Δm***	***TITAN Δm***	***(Expected)Yield***	***Ion source***
^{49}K	1.26 s	70 keV	$< 1.10^{-8}$	$2•10^5$	Surface
^{50}K	472 ms	280 keV	$< 1.10^{-8}$	$1•10^4$	Surface
^{51}K	365 ms	unknown	$< 1.10^{-8}$	$2•10^3$	Surface
^{52}K	105 ms	unknown	$< 1.10^{-8}$	$1•10^3$	Surface
^{53}K	30 ms	unknown	1.10^{-8}	$5•10^2$	Surface
^{51}Ca	10 s	90 keV	$< 5.10^{-9}$	$9•10^4$	TRILIS
^{52}Ca	4.6 s	700 keV	$< 5.10^{-9}$	$8•10^3$	TRILIS
^{53}Ca	90 ms	unknown	5.10^{-9}	$7•10^2$	TRILIS
^{51}Sc	12.4 s	20 keV	$< 5.10^{-9}$	$1•10^5$	Surface
^{52}Sc	8.6 s	190 keV	$< 5.10^{-9}$	$8•10^3$	Surface
^{53}Sc	> 3 s	unknown	5.10^{-9}	$1•10^3$	Surface

The experiment will be carried out with the TITAN facility. The isotopes from ISAC will be delivered to the experiment located in the low-energy area of ISAC I. The continuous beam will be brought into the linear cooler and buncher RFQ (RFCT), where it will be cooled via interactions with buffer gas, followed by bunched extraction. The kinetic energy of the beam extracted from this device can be adjusted and will be ~ 2-4 keV.

The ion bunch is transferred to the Electron Beam Ion Trap (EBIT) for charge breeding. The ions will be stored and charge bred for a specific time and the electron beam energy can be adjusted. Then the ion bunch is mass-to-charge selected employing two Wien filters (WIFI 1&2). This provides a beam of only one charge state, and eliminates possible isobaric contamination. The final step is the mass measurement in a Penning trap (MPET) employing a time-of-flight method. A description of the system can be found in [14,15] and a schematic is shown in figure 4.

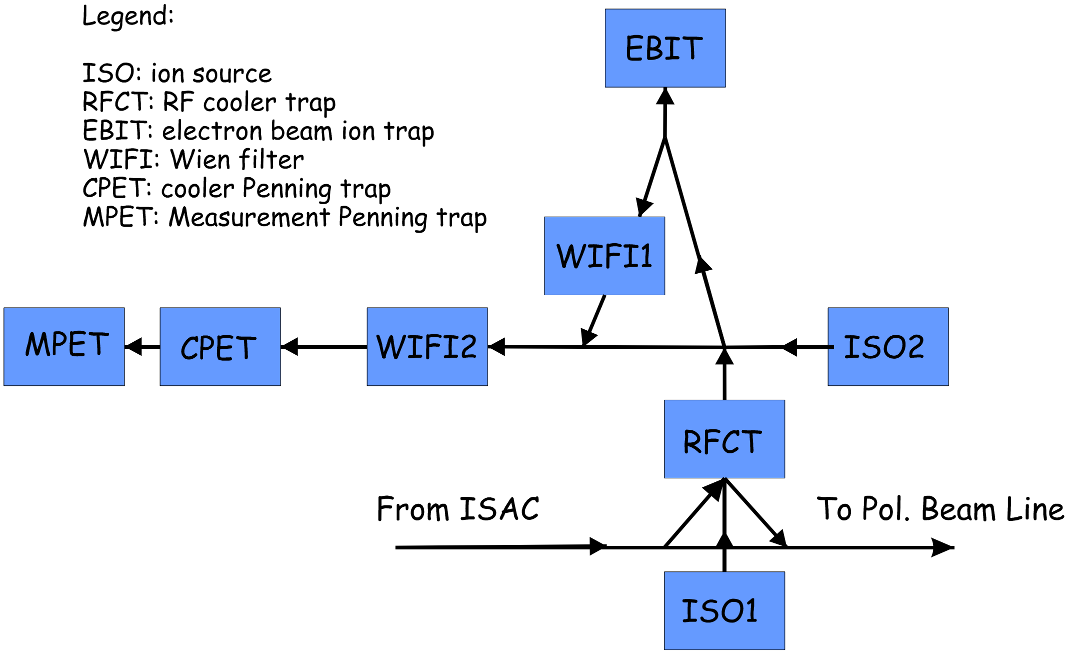

Fig. 4 Schematic of the final layout of TITAN.

The actual mass measurement is done in the following way using the Penning trap mass spectrometer. Penning traps are the most precise devices to measure masses and our system is designed to carry

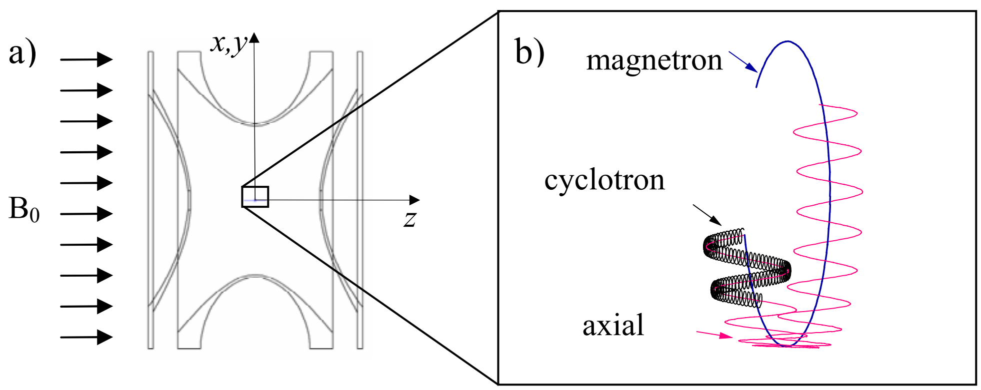

Figure 5. Typical Penning trap a) the geometry and coordinate system; the hyperbolic electrodes create harmonic potential of the form $V(x,y,z) = A(z^2 - (x^2+y^2)/2)$; uniform magnetic field is directed along z-axis $\vec{B} = B_0\hat{z}$. b) ion motion inside the Penning trap consists of three characteristic modes. Along z-axis ion oscillates with axial frequency ω_z. In the x,y-plane the ion motion is a combination of two circular motions with fast modified cyclotron frequency ω_+ and slow magnetron frequency ω_-.

out measurements of atomic masses with an accuracy of $\delta m/m<1\cdot 10^{-8}$, even for radioactive isotopes with half-lives well below 100 ms. In the center of such a spectrometer is the set of hyperbolic electrodes placed in the strong magnetic field, schematically shown in figure 5.

The measurement consists of the following steps.

1. Ion injection. The electrostatic potential is removed and a few ions are allowed to drift into the trap. When the ions are in the trap, the potential is raised to confine them. The closing time should be optimized so that the energy of the resulting axial oscillations is minimal. The ion motion after injection is mostly magnetron and axial oscillation, with minimal cyclotron motion.

2. Quadrupole RF excitation. An external RF field of the form $V_Q = V_Q^{(0)}\,(x^2 - y^2)\times \cos(\omega_Q t)$ is overlapped onto the electrostatic trapping potential for the measurement time interval T_{RF}. It converts the magnetron motion into the cyclotron motion of the same amplitude if the resonant condition

$$\omega_Q = \omega_+ + \omega_- = \omega_c = \frac{qB}{m}$$

is satisfied. The width of this resonance is given by the inverse of the excitation time T_{RF}, which determines the resolving power of this measurement method

$$\frac{m}{\delta m} \propto \omega_c T_{RF}\sqrt{N} = \frac{qB}{m} T_{RF}\sqrt{N} \quad ,$$

where *N* is the statistical improvement factor. Ideally one would try to increase the excitation time as much as possible. However, in the case of stable ions, this is limited by the storage time in the trap, and in our case of short-lived isotopes it is limited by the decay half-life of the ion.

3. Ejection and TOF measurement. After RF excitation the ions are released from the trap by gradually lowering the electrostatic potential along *z*-axis. The resonantly created cyclotron motion has the same amplitude as the initial magnetron motion. Since $\omega_+/\omega_- >>1$ (typically by several orders of magnitude) the energy and magnetic moment of the ion are drastically increased during the RF excitation. Upon ejection, the ion drifts outside the magnetic field region. On its way it passes through the region with the high gradient of the magnetic field. Here, the ions are accelerated proportionally to their magnetic moment. Thus the ions with high magnetic moment will have a shorter time-of-flight (TOF). This allows one to unambiguously detect the resonant conversion of the magnetron motion into the cyclotron motion, hence the resonant frequency, which is directly proportional to the mass. The schematic and an example is depicted in figure 6.

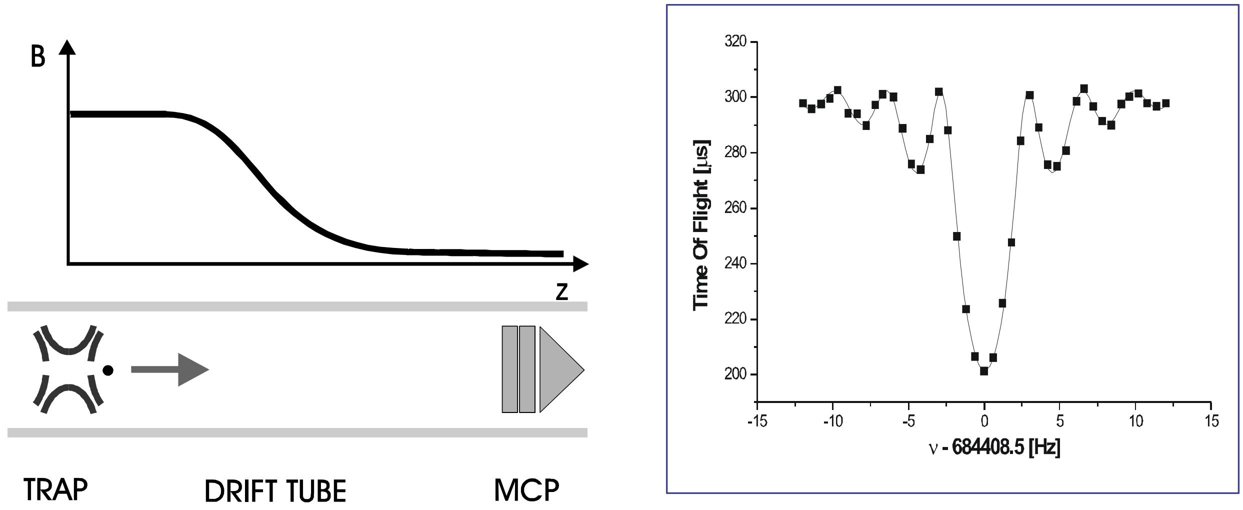

Fig. 6 Left: schematic of the TOF method, where the released ions move through the inhomogeneous magnetic field; right: TOF spectrum, shown is the excitation frequency versus the TOF. The minimum resonance corresponds to the cyclotron frequency, hence allows the mass determination.

Figure 7 shows the relative accuracy of Penning trap spectrometers as a function of measurement time, in sets of magnetic field strength *B* and charge state *q* of the ions. The TITAN system with a magnetic field of 4T will allow measurements with accuracies of better than $\delta m/m < 1 \cdot 10^{-8}$ on isotopes with half-lives as short as 20 ms, when ions with charge states of q = 20 are used.

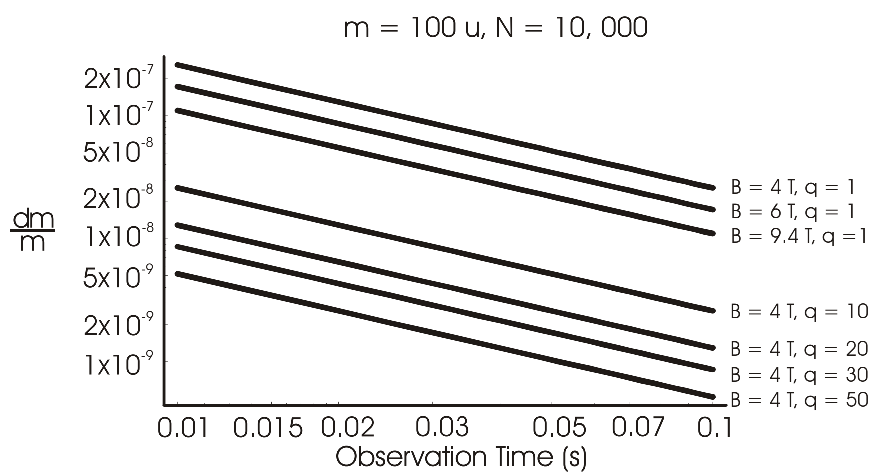

Fig.7 Relative accuracy of the Penning trap measurement as a function of observation time (typically two nuclear half-lives correspond to the applicable observation time). The different sets of graphs represent different charge states q and different magnetic field strength B. The case shown is for 10 000 ions at mass 100.

3. Requested beam time

The requested beam time is based on the assumed efficiency (60% for cooling, 60% for breeding, 80% for cleaning and 50% for measuring), a reasonable constant radioactive beam current, required time for magnetic field calibrations for the measurement magnet, and optimization procedures for the EBIT.

For the most exotic nuclei, the following estimation could be made:

For ^{53}Sc (0.9s), 700 ions/s are expected. The measurement will be carried out by breeding the Sc to charge state q =19 (breeding time about 30 ms at 4500 eV electron beam energy), corresponding to the closed He-shell structure. At a Penning trap excitation time of 100 ms and N=3000 a resolution of $\delta m/m = 5.10^{-9}$ can be reached.

For ^{53}Ca (90ms), 700 ions/s are expected. The measurement will be carried out by breeding the Ca to charge state q =18 (breeding time about 30 ms at 4100 eV electron beam energy), corresponding to the closed He-shell structure for Ca, but only breeding to a maximum of a 3-electron system for Sc. At a penning trap excitation time of 100 ms and N=3000 a resolution of $\delta m/m = 5.10^{-9}$ can be reached.

For ^{53}K (30ms), 500 ions/s are expected. The measurement will be carried out by breeding the K to charge state q = 17 (breeding time about 30 ms at 3600 eV electron beam energy), corresponding to the closed He-shell structure only for K, excluding heavier isobar contamination. At a penning trap excitation time of 30 ms and N=3000 a resolution of $\delta m/m = 1.10^{-8}$ can be reached.

Summarizing the duty cycle in the case of ^{53}Sc and for 700 incoming ions /s,
- 100 ms cooling × 60% efficiency × decay losses = 36 ions
- 30 ms breeding × 60% efficiency × decay losses = 21 ions
- 100 ms cleaning × 80% efficiency × decay losses = 14 ions
- 100 ms measuring × 50% efficiency × decay losses = 6 ions

we obtained an average of 6 ions per cycle in the measurement Penning trap. The same estimation could be carried out for ^{53}Ca and ^{53}K. Due to their shorter halt life, the cycle will have to be optimized to get around 1 ion per cycle. The measurement will be difficult in the case of ^{53}K ($T_{1/2}$ = 30 ms) but may be possible as no cleaning time will be necessary (no contamination is expected after the charge breeding).

We requested a total of 20 shifts. 3 shifts will be allotted for the set-up of each elements (Sc, Ca, K) and 1 shift for each isotope measurements. This time estimate could be adjusted, within the 20 shifts, according to each isotope. The measurements don't need to be allocated in a single experiment but could be broken up to allow for more flexibility and additional off-line optimization.

References:

[1] E418A accepted GANIL experiment, H. Savajols et al.
[2] NSCL mass measurement of neutron-rich nuclei, M.Matos et al.
[3] T. Otsuka et al., *Phys. Rev. Lett.* **87**, 2502 (2001)
[4] B.Pfeiffer et al., Z.Phys. A357, 235 (1997)
[5] W. Mittig et al., *Ann. Rev. Nucl. Sci.* **47**, 27 (1997)
[6] N. A. Orr et al., *Phys. Lett. B* **258**, 29 (1991)
[7] T. Motobayashi et al., *Phys. Lett. B* **346**, 9 (1995)
[8] A. Poves et al., *Nucl. Phys. A* **571**, 221 (1994)
[9] 0. Sorlin et al., *Phys. Rev. C* **47**, 2941 (1993)
[10] T. Glasmacher et al., *Phys. Lett. B* **395**, 163 (1997)
[11] F. Sarazin et al., *Phys. Rev. Lett*. **84**, 5062 (2000)
[12] M. Honma et al., *Phys. Rev. C* **65**, 1301R (2002)
[13] Y. Bai et al., ENAM98, AIP Conf. Proc. No. 455, p. 90.
[14] J. Dilling et al. NIM B 294(2003) 92 & J Dilling et al Int J Mass Spec 251 (2006) 198
[15] V. Ryjkov et al. Euro.J. Phys. A25(2005) 1.53

- *Shape coexistence and the N=28 Shell Closure far from stability.*
  F. Sarazin, H. Savajols, W. Mittig, F. Nowacki, N.A. Orr, Z. Ren, P. Roussel-Chomaz, G. Auger, D. Baiborodin, A.V. Belozyorov, C. Borcea, E. Caurier, Z. Dlouhy, A. Gillibert, A.S. Lalleman, M. Lewitowicz, S.M. Lukyanov, F. de Oliveira, Y.E. Panionzhkevich, D. Ridikas, H. Sakurai, O. Tarasov, A. de Vismes.
  Phys. Rev. Lett. **84**, 5062 (2000).

- *Observation of the ^{11}N ground state.*
  A. Lepine-Szily, J. M. Oliveira , A. N. Ostrowski, H. G.Bohlen, R. Lichtenthaler, A. Di Pietro, A. Laird, G.F. Lima, L. Maunoury, F. Oliveira, P. Roussel-Chomaz, H. Savajols, W. Trinder, A. C. C.Villari, A. de Vismes.
  Phys.Rev.Lett. **84**, 4056 (2000).

- *Deformed Rotational Cascades in ^{152}Dy : Further evidence for shape coexistence at high spin*
  M.B.Smith, D.E.Appelbe, P.J.Twin, C.W.Beausang, F.A.Beck, M.A.Bentley, D.M.Cullen, D.Curien, P.J.Dagnall, G.de France, G.Duchene, S.Erturk, Ch.Finck, B.Haas, I.M.Hibbert, J.C.Lisle, B.M.Nyako, C.D.O'Leary, C.Rigollet, H.Savajols, J.Simpson, O.Stezowski, J.Styczen, J.P.Vivien, K.Zuber.
  Phys.Rev. **C61**, 034314 (2000).

- *Measurement of proton production cross sections with 100MeV deuterons on thin target.*
  D.Ridikas, W.Mittig, H.Savajols, P.Roussel-Chomaz, S.V.Fortsch, J.J.Lawrie, G.F.Steyn.
  Phys. Rev. **C63**, 014610 (2001).

- *High-Spin States in the ^{155}Er.*
  N.Nica, G.Duchêne, V.E.Iacob, J.Dudek, F.A.Beck, T.Byrshi, D.Curien, G.deFrance, B.Haas, B.Kharraja, D.Prévost, C.Petrache, H.Savajols, J.P.Vivien, L.Han, K.Zuber, M.Aiche, M.M.Aléonard, G.Barreau, J.F.Chemin, J.N.Scheurer, C.W.Beausang, S.Clarke, P.J.Dagnall, M.Smith, P.J.Twin, J.Simpson and M.A.Bentley.
  Phys.Rev. **C64**, 034313 (2001).

- *A determination of the $^{6}He+p$ interaction potential.*
  A. de Vismes, , P. Roussel-Chomaz, W. Mittig, A. Pakou, N. Alamanos, F. Auger, J.C. Angelique, J. Barette, A.V. Belozyorov, C. Borcea, W.N. Catford, M.D. Cortina-Gil, Z. Dlouhy, A. Gillibert, V. Lapoux, A. Lepnie-Szily, S.M. Lukyanov, F. Marie, A. Musumarra, F. deOliveira, N.A. Orr, S. Ottini-Hustache, Y.E. Panionzhkevich, F. Sarazin, H. Savajols, N. Skobelev.
  Phys. Lett. **B505** (2001) 15.

- *Direct Reactions Involving Exotic Nuclei ^{8}He and ^{5}H*
  G.M.Ter-Akopian, D.D.Bogdanov, A.S.Fomichev, Yu.Ts.Oganessian, A.M.Rodin, S.I.Sidorchuk, S.V.Stepantsov, R.Wolski, P.Roussel-Chomaz, W.Mittig, H.Savajols, M.S.Golovkov, A.A.Korsheninnikov, I.Tanihata, E.A.Kuzmin, E.Yu.Nikolsky, A.A.Ogloblin.
  Acta Phys.Hung.N.S. **14**, 395 (2001).

- *Radiative proton capture on ^{6}He.*
  E.Sauvan, F.M.Marques, H.W.Wilschut, N.A.Orr, J.C.Angelique, C.Borcea, W.N.Catford, N.M.Clarke, P.Descouvemont, J.Diaz, S.Grevy, A.Kugler, V.Kravchuk, M.Labiche, C.Le Brun,

E.Lienard, H.Lohner, W.Mittig, R.W.Ostendorf, S.Pietri, P.Roussel-Chomaz, M.G.Saint Laurent, H.Savajols, V.Wagner, N.Yahlali.
Phys.Rev.Lett. **87**, 042501 (2001).

- *Reaction cross section measurements on stable and neutron rich nuclei as a probe of the interaction potential.*
  A. de Vismes, , P. Roussel-Chomaz, W. Mittig, A. Pakou, N. Alamanos, F. Auger, J.C. Angelique, J. Barette, A.V. Belozyorov, C. Borcea, W.N. Catford, M.D. Cortina-Gil, Z. Dlouhy, A. Gillibert, V. Lapoux, A. Lepnie-Szily, S.M. Lukyanov, F. Marie, A. Musumarra, F. deOliveira, N.A. Orr, S. Ottini-Hustache, Y.E. Panionzhkevich, F. Sarazin, H. Savajols, N. Skobelev.
  Nucl.Phys. **A706**, 295 (2002).

- *Superheavy hydrogen ^{5}H and Spectroscopy of ^{7}He.*
  A.A. Korsheninnikov, M.S. Golovkov, I. Tanihata, A.M. Rodin, A.S. Fomichev, M.L. Chelnokov, S.I. Sidorchuk,W. Mittig, P. Roussel-Chomaz, H. Savajols, E.A. Kuzmin, E.Yu. Nikolskii, A.A. Oglobin.
  Yad.Fiz. **65**, 696 (2002).
  Phys.Atomic Nuclei **65**, 664 (2002).

- *Shape coexistence and the N = 20 shell closure far from stability by inelastic scattering*
  W.Mittig, H.Savajols, D.Baiborodin, J.M.Casandjian, C.E.Demonchy, P.Roussel-Chomaz, F.Sarazin, Z.Dlouhy, J.Mrazek, A.V.Belozyorov, S.M.Lukyanov, Y.E.Penionzhkevich, N.Alamanos, A.Drouart, A.Gillibert, C.Jouanne, V.Lapoux, E.Pollacco, A.Korichi, J.A.Scarpaci
  Eur.Phys.J. **A 15**, 157 (2002).

- *Characteristics of Neutron-Rich Nuclei Around Shell Closures N=20 and 28.*
  Z.Dlouhy, J.C.Angelique, R.Anne, G.Auger, D.Baiborodin, C.Borcea, E.Caurier, A.Gillibert, S.Grevy, D.Guillemaud-Mueller, A.S.Lalleman, M.Lewitowicz, S.M.Lukyanov, W.Mittig, J.Mrazek, A.C.Mueller, F.Nowacki, F.de Oliveira, N.Orr, R.D.Page, Yu.E.Penionzhkevich, F.Pougheon, A.T.Reed, Z.Ren, D.Ridikas, P.Roussel-Chomaz, M.G.Saint-Laurent, H.Sakurai, F.Sarazin, H.Savajols, O.Sorlin, O.Tarasov, A.de Vismes, J.Winfield.
  Nucl.Phys. **A701**, 189c (2002).

- *Observation of the Particle-Unstable Nucleus ^{10}N .*
  A. Lepine-Szily, J. M. Oliveira , V. Vanin, A. N. Ostrowski, R. Lichtenthaler, A. Di Pietro, V. Guimaraes, A. Laird, L. Maunoury, G.F. Lima, L. Maunoury, F. deOliveira, P. Roussel-Chomaz, H. Savajols, W. Trinder, A. C. C.Villari, A. de Vismes.
  Phys.Rev. **C65**, 054318 (2002).

- VAMOS : a VAriable MOde hight acceptance Spectrometer for identifying reaction products induced by SPIRAL beams.
  H. Savajols for the VAMOS collaboration.
  Proceeding of the 14th International Conference on Electromagnetic Isotope Separators and Techniques Related to their Applications, Victoria, BC, Canada, 6-10 May 2002.
  Nucl. Inst. and Meth. **B 204** (2003) 146.

- Structure of light exotic nuclei 6,8He and 10,11C from (p,p') reactions.

V.Lapoux, N.Alamanos, F.Auger, A.drouart, A.Gillibert, C.Jouanne, G.Lobo, L.Nalpas, A.Obertelli,, E.Pollacco, R.Raabe, F.Skaza, J-L.Sida, D.Beaumel, E.Becheva, Y.Blumenfeld, F.Delaunay, L.Giot, E.Khan, A.Lagoyannis, A.Musumarra, P.Navratif, A.Pakou, P.Roussel-Chomaz, H.Savajols, J-A. Scapaci, S.Stepensov, R.Wolski and T.Zerguerras.
Nuclear Physics **A722** (2003) 49c.

- New Target and detection methods : active detectors.
  W.Mittig, H.Savajols, C.E.Demonchy, L.Giot, P.Roussel-Chomaz, H.Wang, G.ter-Akopian, A.Fomichev, M.S.Golovkov, S.Stepensov, R.Wolski, N.Alamanos, A.Drouart, A.Gillibert, V.Lapoux and E.Pollaco.
  Nuclear Physics **A722** (2003) 10c.

- Structure of light exotic nuclei ^{6,8}He and ^{10,11}C from (p,p') reactions
  V. LapouxE-mail The Corresponding Author, a, N. Alamanosa, F. Augera, A. Drouarta, A. Gilliberta, C. Jouannea, G. Loboa, L. Nalpasa, A. Obertellia, E. Pollaccoa, R. Raabea, F. Skazaa, J. -L. Sidaa, D. Beaumelb, E. Bechevab, Y. Blumenfeldb, F. Delaunayb, L. Giotc, E. Khanb, A. Lagoyannisd, A. Musumarrae, P. Navràtiff, A. Pakoud, P. Roussel-Chomazc, H. Savajols, J. -A. Scarpacib, S. Stepantsovg, R. Wolskig and T. Zerguerrasb
  Nuclear Physics **A722** (2003) 49c.

- Elastic scattering of ^{8}He on ^{4}He and 4n system
  R.Wolski, S.I.Sidorchuk, G.M.Ter-Akopian, A.S.Fomichev, A.M.Rodin, S.V.Stepantsov, W.Mittig, P.Roussel-Chomaz, H.Savajols, N.Alamanos, F.Auger, V.Lapoux, R.Raabe, Yu.M.Tchuvil'sky, K.Rusek
  Nucl.Phys. **A722**, 55c (2003)

- *Experimental Evidence for the Existence of ^{7}H and for a Specific Structure of ^{8}He*
  A.A.Korsheninnikov, E.Yu.Nikolskii, E.A.Kuzmin, A.Ozawa, K.Morimoto, F.Tokanai, R.Kanungo, I.Tanihata, N.K.Timofeyuk, M.S.Golovkov, A.S.Fomichev, A.M.Rodin, M.L.Chelnokov, G.M.Ter-Akopian, W.Mittig, P.Roussel-chomaz, H.Savajols, E.Pollacco, A.A.Ogloblin, M.V.Zhukov.
  Phys.Rev.Lett. **90**, 082501 (2003).

- *Search for t+t clustering in ^{6}He*
  L.Giot, P.Roussel-Chomaz, S.Pita, N.Alamanos, F.Auger, M.-D.Cortina-Gil, Ch-E.Demonchy, J.Fernandez, C.Jouanne, A.Gillibert, V.Lapoux, L.Nalpas, E.C.Pollacco, A.Rodin, A.Pakou, K.Rusek, H.Savajols, J.-L.Sida, S.Stepantsov, G.Ter-Akopian, R.Wolski
  Nucl.Phys. **A738**, 426 (2004)

- *Observation of bound excited states in ^{15}B*
  M. Stanoiu, M. Belleguic, Zs. Dombrádi, D. Sohler, F. Azaiez, B. A. Brown, M. J. Lopez-Jimenez, M. G. Saint-Laurent, O. Sorlin, Yu.-E Penionzhkevich, N. L. Achouri, J. C. Angélique, C. Borcea, C. Bourgeois, J. M. Daugas, F. De Oliveira-Santos, Z. Dlouhy, C. Donzaud, J. Duprat, S. Grévy, D. Guillemaud-Mueller, S. Leenhardt, M. Lewitowicz, S. M. Lukyanov, W. Mittig, M. G. Porquet, F. Pougheon, P. Roussel-Chomaz, H. Savajols, Y. Sobolev, C. Stodel and J. Timár
  Eur. Phys. J. **A 22**, 5-8 (2004)

- *N = 14 and 16 shell gaps in neutron-rich oxygen isotopes*

M.Stanoiu, F.Azaiez, Zs.Dombradi, O.Sorlin, B.A.Brown, M.Belleguic, D.Sohler, M.G.Saint Laurent, M.J.Lopez-Jimenez, Y.E.Penionzhkevich, G.Sletten, N.L.Achouri, J.C.Angelique, F.Becker, C.Borcea, C.Bourgeois, A.Bracco, J.M.Daugas, Z.Dlouhy, C.Donzaud, J.Duprat, Zs.Fulop, D.Guillemaud-Mueller, S.Grevy, F.Ibrahim, A.Kerek, A.Krasznahorkay, M.Lewitowicz, S.Leenhardt, S.Lukyanov, P.Mayet, S.Mandal, H.van der Marel, W.Mittig, J.Mrazek, F.Negoita, F.De Oliveira-Santos, Zs.Podolyak, F.Pougheon, M.G.Porquet, P.Roussel-Chomaz, H.Savajols, Y.Sobolev, C.Stodel, J.Timar, A.Yamamoto
Phys.Rev. **C 69**, 034312 (2004)

- Study of drip line nuclei through two-step fragmentation
  M.Stanoiu , F.Azaiez, F.Becker, M.Belleguic, C.Borcea, C.Bourgeois, B.A.Brown, Z.Dlouhy, Z.Dombradi, Z.Fulop, H.Grawe, S.Grevy, F.Ibrahim, A.Kerek, A.Krasznahorkay, M.Lewitowicz, S.Lukyanov, H.van der Marel, P.Mayet, J.Mrazek, S.Mandal, D.Guillemaud-Mueller, F.Negoita, Y.E.Penionzhkevich, Z.Podolyak, P.Roussel-Chomaz, M.G.Saint Laurent, H.Savajols, O.Sorlin, G.Sletten, D.Sohler, J.Timar, C.Timis, A.Yamamoto
  Eur.Phys.J. **A 20**, 95 (2004)

- *Study of light proton-rich nuclei by complete kinematics measurements*
  T.Zerguerras, B.Blank, Y.Blumenfeld, T.Suomijarvi, D.Beaumel, B.A.Brown, M.Chartier, M.Fallot, J.Giovinazzo, C.Jouanne, V.Lapoux, I.Lhenry-Yvon, W.Mittig, P.Roussel-Chomaz, H.Savajols, J.A.Scarpaci, A.Shrivastava, M.Thoennessen
  Eur.Phys.J. **A 20**, 389 (2004)

- *Study of ^{19}Na at SPIRAL*
  F.de Oliveira Santos, P.Himpe, M.Lewitowicz, I.Stefan, N.Smirnova, N.L.Achouri, J.C.Angelique, C.Angulo, L.Axelsson, D.Baiborodin, F.Becker, M.Belleguic, E.Berthoumieux, B.Blank, C.Borcea, A.Cassimi, J.M.Daugas, G.de France, F.Dembinski, C.E.Demonchy, Z.Dlouhy, P.Dolegieviez, C.Donzaud, G.Georgiev, L.Giot, S.Grevy, D.Guillemaud-Mueller, V.Lapoux, E.Lienard, M.J.Lopez Jimenez, K.Markenroth, I.Matea, W.Mittig, F.Negoita, G.Neyens, N.Orr, F.Pougheon, P.Roussel-Chomaz, M.G.Saint-Laurent, F.Sarazin, H.Savajols, M.Sawicka, O.Sorlin, M.Stanoiu, C.Stodel, G.Thiamova, D.Verney, A.C.C.Villari
  Eur.Phys.J. **A 24**, 237 (2005)

- *Investigation of ^{6}He cluster structures*
  L.Giot, P.Roussel-Chomaz, C.E.Demonchy, W.Mittig, H.Savajols, N.Alamanos, F.Auger, A.Gillibert, C.Jouanne, V.Lapoux, L.Nalpas, E.C.Pollacco, J.L.Sida, F.Skaza, M.D.Cortina-Gil, J.Fernandez-Vazquez, R.S.Mackintosh, A.Pakou, S.Pita, A.Rodin, S.Stepantsov, G.M.Ter-Akopian, K.Rusek, I.J.Thompson, R.Wolski
  Phys.Rev. C **71**, 064311 (2005)

- *Structure of low-lying states of ^{10,11}C from proton elastic and inelastic scattering*
  C. Jouanne, V. Lapoux, F. Auger, N. Alamanos, A. Drouart, A. Gillibert, G. Lobo, A. Musumarra, L. Nalpas, E. Pollacco, J.-L. Sida, M. Trotta, Y. Blumenfeld, E. Khan, T. Suomijärvi, T. Zerguerras, P. Roussel-Chomaz, H. Savajols, A. Lagoyannis and A. Pakou
  Phys. Rev. **C 72**, 014308 (2005)

- Reaction cross-sections and reduced strong absorption radii of nuclei in the vicinity of closed shells N = 20 and N = 28

A. Khouaja, A. C. C. Villari, M. Benjelloun, G. Auger, D. Baiborodin, W. Catford, M. Chartier, C. E. Demonchy, Z. Dlouhy, A. Gillibert, L. Giot, D. Hirata, A. Lépine-Szily, W. Mittig, N. Orr, Y. Penionzhkevich, S. Pitae, P. Roussel-Chomaz, M. G. Saint-Laurent and H. Savajols
Eur.Phys.J. **A 25**, 223 (2005)

- First experiments on transfer with radioactive beams using the TIARA array
  W. N. Catford, R. C. Lemmon, M. Labiche, C. N. Timis, N. A. Orr, L. Caballero, R. Chapman, M. Chartier, M. Rejmund, H. Savajols and the TIARA Collaboration
  Eur.Phys.J. **A 25**, 245 (2005)

- Study of the ground-state wave function of ^{6}He via the ^{6}He(p, t) transfer reaction
  L. Giot, P. Roussel-Chomaz, N. Alamanos, F. Auger, M. -D. Cortina-Gil, Ch. E. Demonchy, J. Fernandez, A. Gillibert, C. Jouanne, V. Lapoux, R. S. Mackintosh, W. Mittig, L. Nalpas, A. Pakou, S. Pita, E. C. Pollacco, A. Rodin, K. Rusek, H. Savajols, J. L. Sida, F. Skaza, S. Stepantsov, G. Ter-Akopian, I. Thompson and R. Wolski
  Eur.Phys.J. **A 25**, 267 (2005)

- Reactions induced beyond the dripline at low energy by secondary beams
  W. Mittig, C. E. Demonchy, H. Wang, P. Roussel-Chomaz, B. Jurado, M. Gelin, H. Savajols, A. Fomichev, A. Rodin, A. Gillibert, A. Obertelli, M. D. Cortina-Gil, M. Caama no, M. Chartier and R. Wolski
  Eur.Phys.J. **A 25**, 263 (2005)

- New mass measurements at the neutron drip-line
  H. Savajols, B. Jurado, W. Mittig, D. Baiborodin, W. Catford, M. Chartier, C. E. Demonchy, Z. Dlouhy, A. Gillibert, L. Giot, A. Khouaja, A. Lépine-Szily S. Lukyanov, J. Mrazek, N. Orr, Y. Penionzhkevich, S. Pita, M. Rousseau, P. Roussel-Chomaz and A. C. C. Villari
  Eur.Phys.J. **A 25**, 23 (2005)

- *Inelastic scattering of N=20 neutron-rich nuclei*.
  H. Savajols, W. Mittig P. Roussel-Chomaz, N. Alamanos, D. 73Baiborodin, A.V. Belozyorov, J.M. Casandjian C.E. Demonchy, Z. Dlouhy, A. Drouart, A. Gillibert, C. Jouanne, A. Korichi, V. Lapoux, S. M. Lukyanov, J. Mrazek, Y.E. Penionzhkevich, E. Pollacco, J.A. Scarpaci, N. Skobelev, F. Sarazin.
  Submitted to Phys. Rev. **C**.