TRIUMF — RESEARCH PROPOSAL

Experiment no.

E874

Title of proposed experiment:

Study of ^{19}Ne α-decay properties related to the hot-CNO breakout reaction ^{15}O(α,γ)^{19}Ne

Name of group: TUDA

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D. Groombridge	U. of Edinburgh	Grad. Student	20%
A.M. Laird	U. of Edinburgh	Grad. Student	30%
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Start of preparations: now

Date ready: October 2000

Completion date: October 2001

Beam time requested:

12-hr shifts	Beam line/channel	Polarized primary beam?
20 (radioactive)	ISAC-HE	na

In explosive hydrogen burning that occurs in cataclysmic events, i.e. (X-ray) Novae, the ^{15}O(α,γ) reaction is the most likely pathway that leads from the (hot-) carbon nitrogen oxygen cycle found in main sequence stars into the nucleosynthesis of proton-rich elements up to mass 100 via the rapid proton capture process. This reaction is also the major energy generating step during the thermonuclear runaway in such stellar events. However, a direct measurement of the ^{15}O(α,γ) reaction is very challanging, due to the low cross section at the relevant astrophysical energies.

It is proposed to investigate properties of this so-called breakout reaction via a study of the relevant α-decays of excited states in ^{19}Ne. These resonances will be populated using an inverse ^{18}Ne(d,p) reaction. The recoiling proton that is produced in this binary reaction uniquely tags the states in ^{19}Ne that have been populated. Moreover, the detection of the ^{19}Ne-ejectiles' decay products α and ^{15}O is greatly improved due to the high laboratory momenta at which they are formed in this inverse kinematics approach. This opens then the opportunity to investigate the relevant branching ratios under advantageous experimental conditions.

Exploratory experiments have been carried out at the radioactive ion beam facility in Louvain-la-Neuve, Belgium, using an especially designed high granularity large solid angle silicon strip detector array. The cross sections measured there show that the advent of radioactive ^{18}Ne beams of intensities in excess of 10^8 ions/sec at ISAC makes a study of the important properties of the ^{15}O(α,γ) reaction using the ^{18}Ne(d,p) approach feasible.

Hence, an experiment is suggested that uses the d(^{18}Ne,p)^{19}Ne*(α)^{15}O reaction at 1.5MeV per nucleon to yield unprecedented information using the TUDA scattering facility and a solid state strip detector array to detect the tagging protons and decay products. The ^{18}Ne-beam should have a minimum intensity of 10^8 ions per sec. A total beamtime of twenty 12 hour long shifts is requested, which is needed to provide the necessary data.

Experimental area

ISAC-HE, TUDA

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

p-Zeolith, 500MeV, cw

Secondary channel ISAC-HE

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

^{18}Ne (unstable) up to 10^{9}s^{-1},1.5MeV per nucleon, ^{18}O (stable), 1.5MeV per nucleon

TRIUMF SUPPORT:

TUDA services as presented to and reviewed by TRIUMF including an electronics cabin and special grounding.

NON-TRIUMF SUPPORT

The TUDA facility, including considerable manpower for setting up and operation will be provided by the University of Edinburgh.

Standard TUDA operation with a short-lived radioactive isotope (^{18}Ne, $T_{1/2}$=1.7s). Low voltage detectors and electronics.

1 Scientific Justification

The main source of nuclear energy production in the majority of so-called main sequence or hydrogen rich stars is the fusion of hydrogen to helium through the proton-proton chain reactions at stellar core temperatures less than $5{\times}10^7$K. However, for temperatures higher than this value, the fusion reaction pathway proceeds via the CNO-cycle. The seed nuclei C, N and O are not consumed during this process; they rather act as catalysts. If, however, the temperature exceeds $5{\times}10^8$K, e.g. in X-ray bursters and maybe even in novae [1], the seed nuclei are rapidly converted into heavier isotopes by a series of α and proton induced capture reactions. This series is initiated by a radiative α capture on the nucleus that has the longest half-life in the hot-CNO cycle, ^{15}O. This produces ^{19}Ne-nuclei, which can be converted into ^{20}Na via radiative proton capture [2] (see figure 1).

Unfortunately, the radiative α capture on ^{15}O is the least well known of these reactions. Since it is at the beginning of this breakout pathway, it will have to be measured if we are to have confidence in the energy release calculation for such events as well as the isotope abundances produced by the rapid proton capture model.

1.1 Importance of the Experiment

The reaction rate coefficient $< \sigma\nu >$ of a radiative α capture through a single resonance at energy E$_r$ in a stellar environment of temperature T is given by

$$< \sigma\nu > \approx \omega\gamma \exp[\tfrac{-E_r}{kT}]$$

where

$$\omega\gamma = \text{spin statistical factor } \times \tfrac{\Gamma_\alpha \Gamma_\gamma}{\Gamma_\alpha + \Gamma_\gamma}.$$

For resonances well below the Coulomb barrier where

$$\Gamma_\alpha << \Gamma_\gamma$$

the approximation given above can be replaced by:

$$< \sigma\nu > \approx \omega\Gamma_\alpha \exp[\tfrac{-E_r}{kT}]$$

Hence, below the Coulomb barrier knowledge of the resonance energy E$_r$ and its α-decay width Γ_α is sufficient to deduce the reaction rate. The α-decay width Γ_α can be calculated from a branching ratio measurement, provided that the total width is known, which in the cases under investigation is totally dominated by Γ_γ partial width. This width might be deduced from states in the mirror nucleus ^{19}Ne [3]. A direct measurement of Γ_γ of the states of interest in ^{19}Ne is currently under way at Louvain-la-Neuve.

Figure 2 shows a scheme of levels in ^{19}Ne situated above the α-decay threshold. The corresponding centre of mass energies in the ^{15}O + α The resonances of particular nuclear astrophysics interest lie a 504keV, 850keV and 1183keV in the ^{15}O + α centre of mass system, corresponding to compound states in ^{19}Ne at 4.033MeV, 4.379MeV and 4.712MeV respectively. They dominate the reaction rates at temperatures that might be found in the cataclysmic scenarios mentioned above (see figure 3). The 4.033MeV resonance is well below the coulomb barrier. Since the resonance energy is known, the reaction rate for the helium burning of ^{15}O can be determined, if the branching ratio can be measured. This is the quantity the proposed experiment is aiming at. Due to the low energy loss the protons formed in the inverse ^{18}(d,p) reaction are a unique tag for the excited states in ^{19}Ne that have been populated. In addition, this single nucleon pick-up reaction will provide sufficient cross section to populate the states of interest abundently enough to measure the small branching ratios involved.

1.2 Competitive Measurements

Up to now, no direct measurements of this reaction for the energy region of nuclear astrophysical interest have been performed. A study of the ^{19}F(^{3}He,t)^{19}Ne*(α)^{15}O reaction gave some useful information concerning states in ^{19}Ne above 4.5MeV excitation energy. However, the states of particular astrophysical interest have not been observed [4]. Indirect methods have used transfer reactions on mirror nuclei [3], to determine the branching ratios of interest. However, the validity of such approaches seems to be questionable [5].

The test experiment mentioned above has taken place at the radioactive beam facility at Louvain-la-Neuve, Belgium. A ^{18}Ne beam of 10^{5}ions/s at an incident energy of 45 MeV has been used to perform the d(^{18}Ne,^{19}Ne*)p reaction on a $(CD_2)_n$-target of 0.4mg/cm^2 thickness. Three LEDA-type silicon strip detector arrays [7] have been used to measure the particles decays of the excited states in ^{19}Ne. A total of 320 strips have been used and both energy and time-of-flight with respect to the cyclotron frequency were recorded for each strip.

The protons produced in this reaction tag the population of specific excited states in ^{19}Ne. A triple coincidence with an α-particle and a heavy fragment having the appropriate angular signature enables the determination of the branching ratios of interest. The set-up was capable of measuring three particle coincidences with a total efficiency of 2.9%. Figure 4 shows a preliminary angular distribution for the protons obtained between 130 and 160 degrees and filtered by the condition that the event has yielded a proton in this angular range [8]. The background from fusion evaporation is featureless and exponentially falling off at these angles, which has been determined performing a reference measurement on a $(CH_2)_n$ target.

This test experiment shows the detection of ≈200 events at the proton energy that tags the population of the 4.033MeV state in ^{19}Ne*. The cross section is of the order of 0.5mb/sr. ¿From first results it is possible to project the likely data yield with improved detector geometry and ^{18}Ne-beam intensity expected at ISAC. This extrapolation shows that the potential to obtain useful information on α branching ratios is unique at the ISAC facility. However, a beam intensity in excess of 10^{8} ^{18}Ne ions/s would be required to get new information on the α-branching ratio of the 4.033MeV state. This beam intensity will be available at ISAC at a suitable energy for this measurement.

Unfortunately, the α-decay of ^{19}Ne nuclei produced in this excited state has not been observed in the test experiment. This is due to the very low branching ratio – an estimate has been given by K. Langanke et al. [9] – and the limited triple coincidence efficiency of 0.4%. However, triple coincidences have been observed from the decay of states with high α branching ratios, e.g. from the excited state at 4.600MeV. These decays are suitable to check the coincidence efficiency in such an experiment.

1.3 Theoretical Calculations

The maximum yield for the inverse ^{18}Ne(d,p) reaction can be expected at around 5MeV per nucleon as can be seen from the results of an exploratory DWBA calculation given in figure 5. The parameters of the potentials in the different channels have been chosen in the following way:

- For the p-^{19}Ne channel the parameters of [10] have been used.
- The excited state in ^{19}Ne is described as pure single particle state using the same parameters for the radius and diffuseness as in the proton case.
- Spin-orbit interaction has been neglected and the depth of the central potential has been adjusted to get the experimental binding energies of the resonances referring to the n-^{18}Ne threshold [11].
- For the resonance at 4.033MeV ($J^\pi=3/2^+$) l=1 has been assumed.
- The d-^{18}Ne optical potentials are taken from [10].

Following this calculation the cross section rises monotonically between 1.0 and ≈5MeV per nucleon. However, the cross section varies much less in the backward hemisphere, due to the rise in the centre of mass velocity. For example the ^{18}O(d,p)^{19}O reaction shows only a variation of about a factor two in the relevant angular range [12]. Hence, performing the proposed experiment at 1.5 MeV per nucleon incident energy will not yield prohibitively low cross sections in the backward hemisphere.

This incident energy also assures that the following conditions are met:

- The recoiling protons produced in the d(^{18}Ne,^{19}Ne*)p reaction need to have sufficient energy to be detected.
- The energy of these protons will be well above the β background produced by the decay of the incident beam particles

A Monte-Carlo simulation using the results from the test experiment have been used to optimise the experimental set-up. Isotropic angular distributions have been used to simulate a worst case scenario. In addition, the energy loss and straggling effects that the particles involved in the reaction undergo have been taken into account.

With the aid of the results of these simulations given in figure 6, one can find the optimal angular ranges to be covered by the set-up to detect the α and ^{15}O decay products, which have originated from excited states of astrophysical interest in ^{19}Ne. The simulations also show that the optimal energy resolution for the protons that tag the populated excited state in ^{19}Ne can be found in the backward hemisphere. This is due to the steep rise in proton energy with angle that occures in the forward hemisphere. From the simulation it is clear that an optimum detection of alpha particle and ^{15}O should cover 0 to 27 degrees. However, the elastic scattering background will make it impossible for a solid state detector array to be used close to 0 degrees. Though for angles larger than 2 degrees such a set-up will be proposed for this experiment.

2 Description of the Experiment

The proposed experimental set-up shown in figure 7 of three silicon strip detector arrays. use one LEDA-type [7] and one RX detector array consisting of 128 and 64 annular strips, respectively. They will cover 33 to 14 degrees and 10 to 2 degrees, respectively. Their purpose will be to detect ^{15}O and α particles from the resonances' decays.

The protons that tag the populated states in ^{19}Ne will be detected in a second LEDA-type detector mounted at backward angles, which consists of 128 strips. All detectors have sufficient thickness to stop the decay products under investigation.

2.1 Experimental Resolution

A precise count rate estimation for the population of the state in ^{19}Ne at 4.033MeV excitation energy is very difficult. During the test experiment a total of 225 protons were detected tagging the formation of a ^{19}Ne* nucleus in this excited state in a 27h run. Taking the singles detection efficiency of 2.9% into account, a total of $\approx$ 7760 of such protons have been produced. Assuming a beam intensity of 10^8 ions per sec and target thickness of 0.4mg/cm^2 a total of $\approx 2\times10^6$ of such protons would be produced, i.e. 80 per second. However, the yield at 1.5MeV per nucleon incident energy might be a factor two lower.

Assuming an improved single event efficiency of 8.5% one can expect to detect $\approx$3 tagging protons per second. In a 144h run a total of $\approx 2\times10^6$ of such protons would be detected. To estimate the branching ratio sensitivity the triple coincidence efficiency has to be taken into account which is 5.2%. A branching ratio of 1 would yield $\approx 1\times10^6$ detected triples. Hence, a branching ratio of 10^{-4} as calculated by Langanke would yield $\approx 1\times10^2$ detected triple coincidences.

3 Readiness

The installation of the TUDA facility has been discussed with the TRIUMF management and it is planned that the detector array, vacuum chamber and electronics are provided by the University of Edinburgh. They will be shipped from there in March to early summer 2000. During that period the electronics cabin will have been constructed by TRIUMF providing shielding from electronic noise and will provide stable temperature conditions. It is forseen that after two months the system will be ready for tests with

α-sources. The system should be operational in September 2000 to take both stable and radioactive beams. This milestone provides a time frame that is flexible enough to deal with unforeseen problems.

4 Beam Time required

^{18}Ne-beam at 1.5MeV per nucleon and 10^8 ions per sec.

• Set-up of spectrometer and calibration	2 shifts
• Measurement on $(CD_2)_n$-target (0.4mg/cm^2):	12 shifts
• Measurement on $(CH_2)_n$-target (0.4mg/cm^2):	2 shifts
• Measurement on ^{12}C-target (0.2mg/cm^2):	2 shifts
• Measurement on ^{197}Au-target (0.2mg/cm^2):	2 shifts
• **Total request**	**20 shifts**

5 Data Analysis

The design of the TUDA data acquisition system is in the final stage and we expact a data handling rate of up to 50000 events per second. Storage on DLT tapes as well as on hard disk is foreseen and off-line analysis in Edinburgh has been secured. The data analysis will follow the same lines as used for the test experiment data obtained in Louvain-la-Neuve.

References

1. J.Andrea, H. Drechsel and S. Starrfield, Astron. Astrophys. **291**, 869 (1994)
2. R.K. Wallace and S.E. Woosley, Astr. J. Suppl. **45** (1980) 389
3. S. Wilmes et al., Phys.Rev. **C52**, R2823 (1995).
4. P.V. Magnus et al., Nucl. Phys. **A506**, (1990) 332.
5. F. de Oliveira et al., Phys.Rev. **C55**, 3149 (1997).
6. A. Champagne and M. Wiescher, Ann. Rev. Nucl. Part. Sci. **42** (1992) 435
7. T. Davinson et al., Nucl. Inst. Meth **A288**, 245 (1990)
8. A.N. Ostrowski et al., J. Phys. **G24** (1998) 1553.
9. K. Langanke et al., Astro. J. **301** 629 (1986).
10. F.G. Perey, Phys. Rev. **131** (1963) 745.
11. D.R. Tilley et al., Nucl. Phys. **A595** (1995) 1.
12. E.J. Stephenson et al., Nucl. Phys. **A331** (1979) 269.

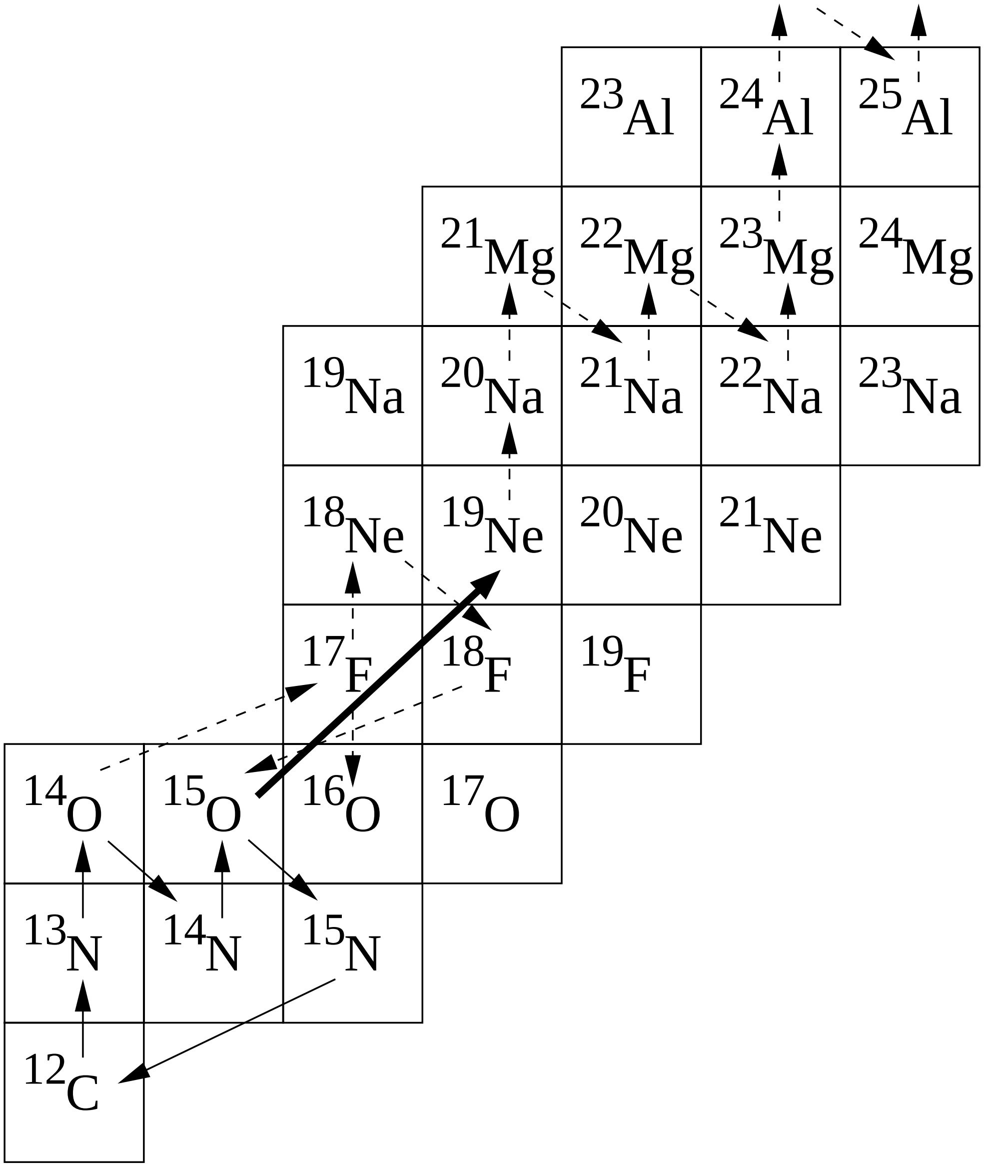

Fig. 1 Sketch of the nuclear reaction network showing the break-out pathway from the hot-CNO cycle directed to heavier proton-rich nuclei.

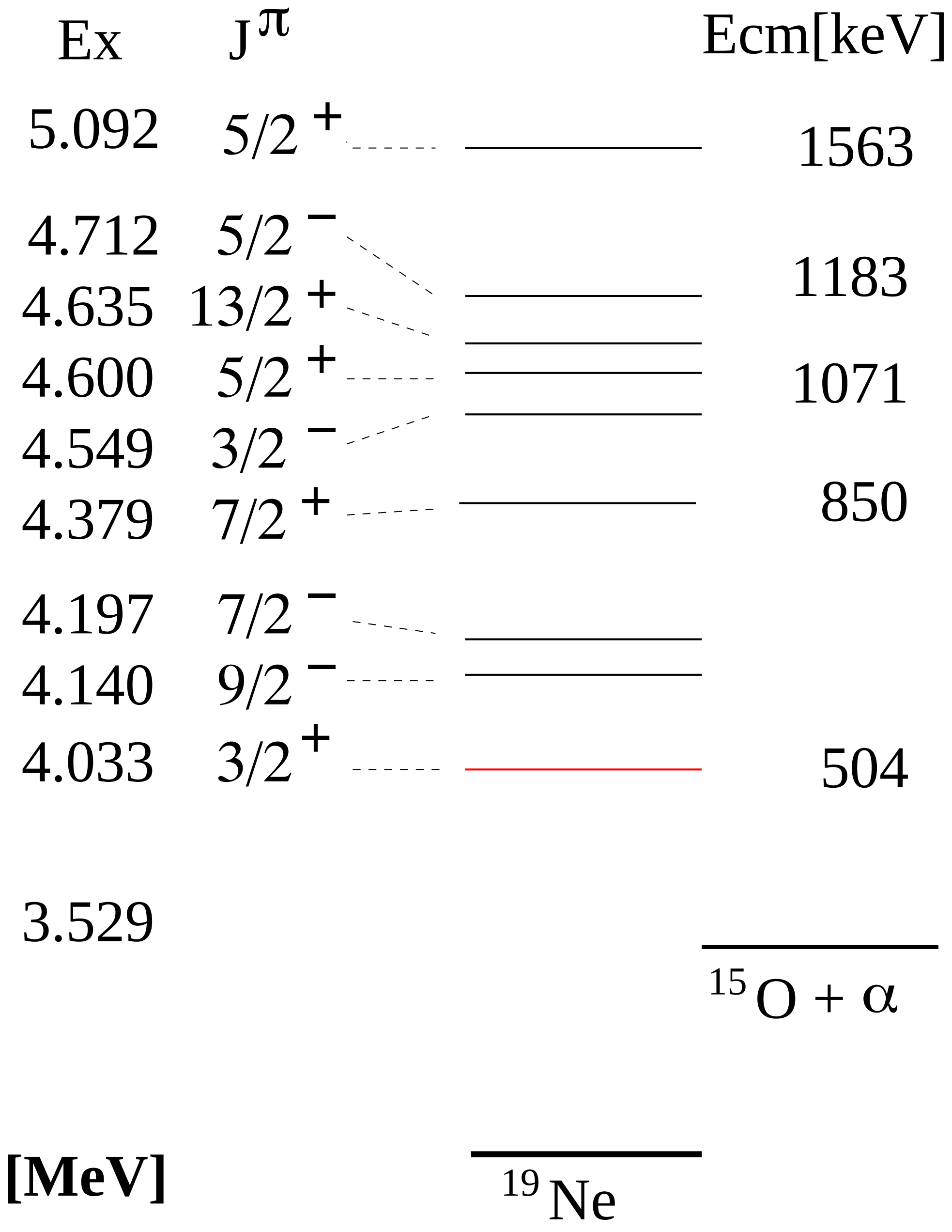

Fig. 2 Level scheme showing spins and resonance energies for excited states in ^{19}Ne of interest, which lie above above the α-decay threshold. In addition the corresponding centre of mass energies in the ^{15}O + α system are also given.

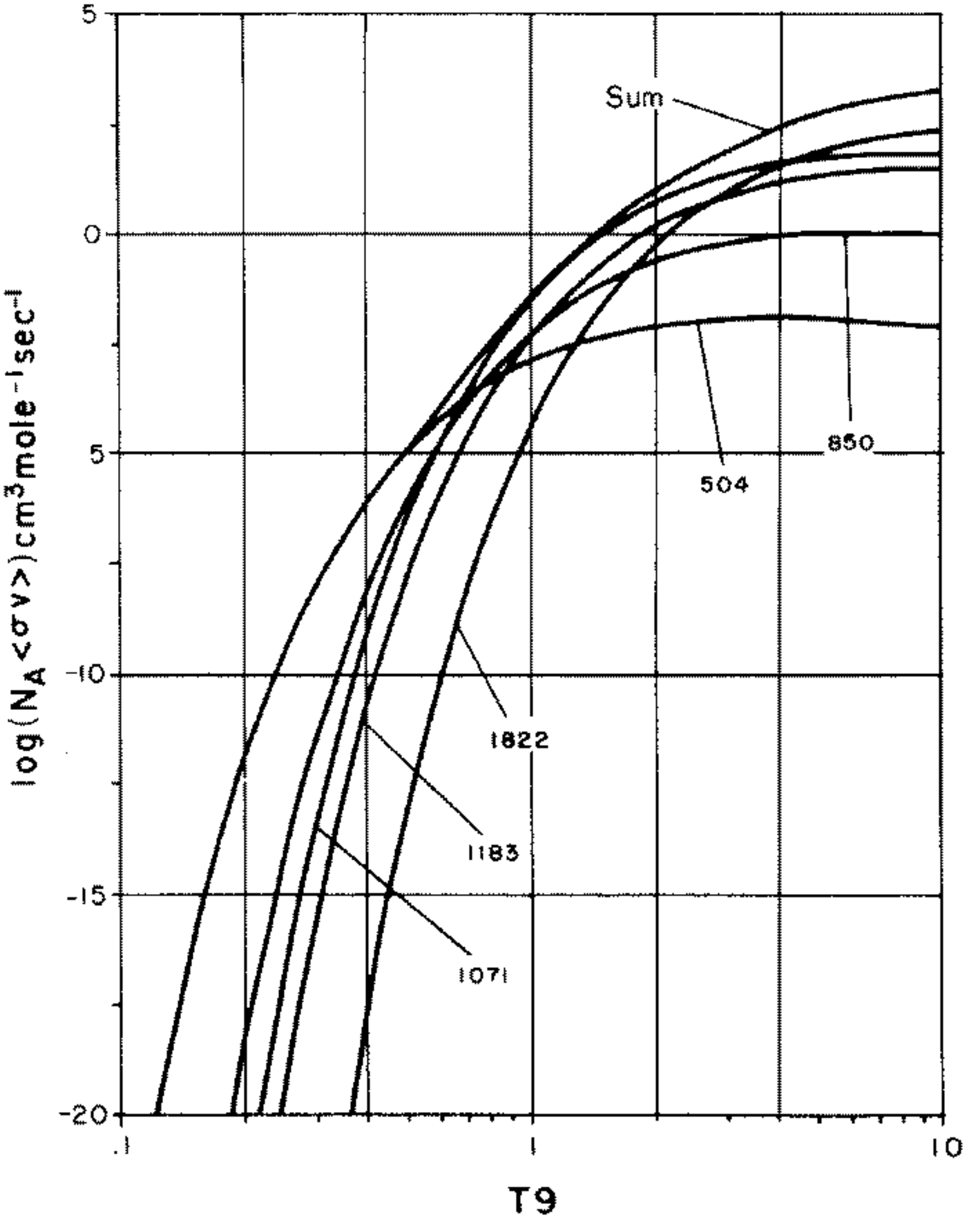

Fig. 3 The ^{15}O(α,γ)^{19}Ne reaction rate as a function of temperature showing the total reaction rate and the contributions of the major resonances calculated by P. Magnus et al. [4].

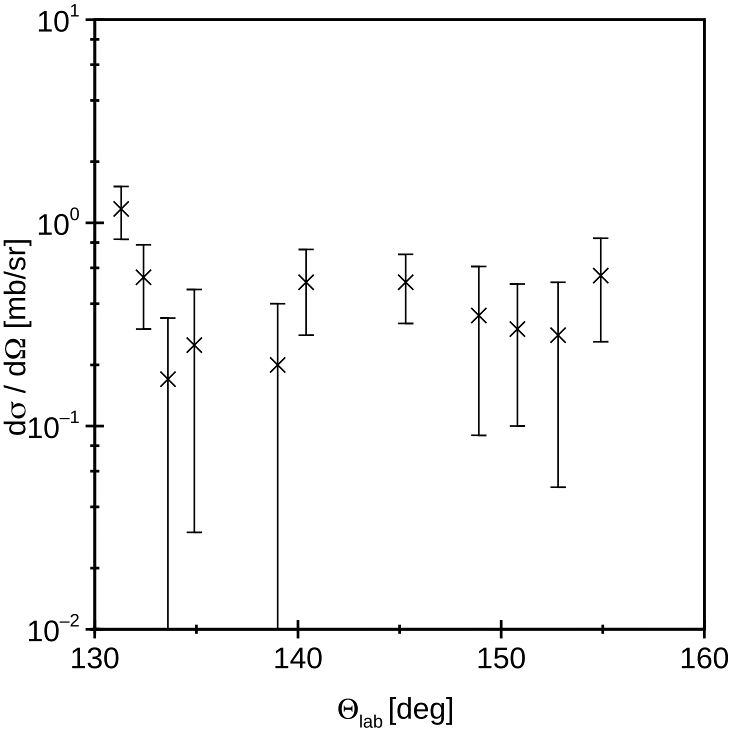

Fig. 4 Angular distribution of the d(^{18}Ne,p)^{19}Ne$^*_{4.033}$ reaction.

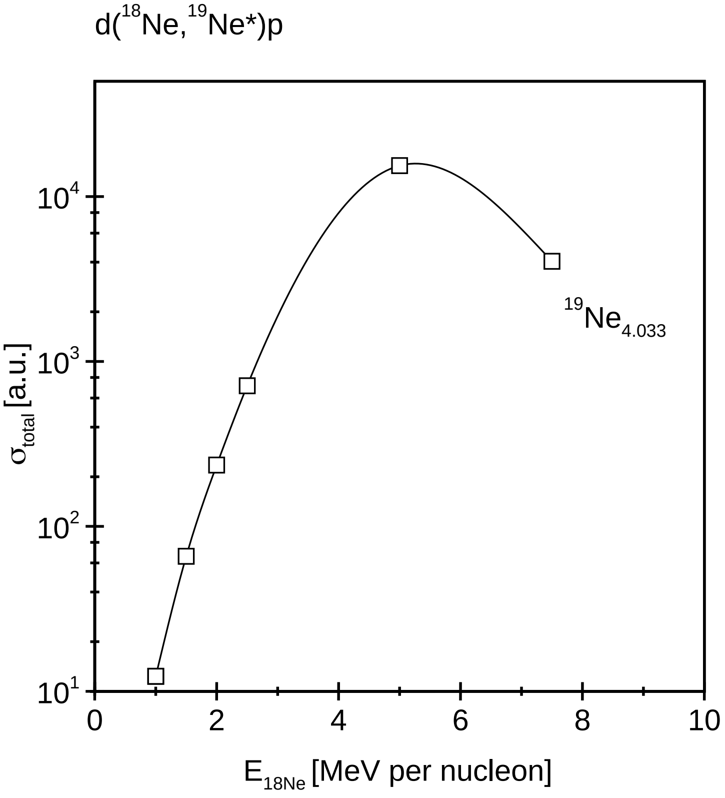

Fig. 5 DWBA-calculation of the energy dependence of the total d(^{18}Ne,^{19}Ne*)p reaction cross section for the formation of the 4.033MeV excited state.

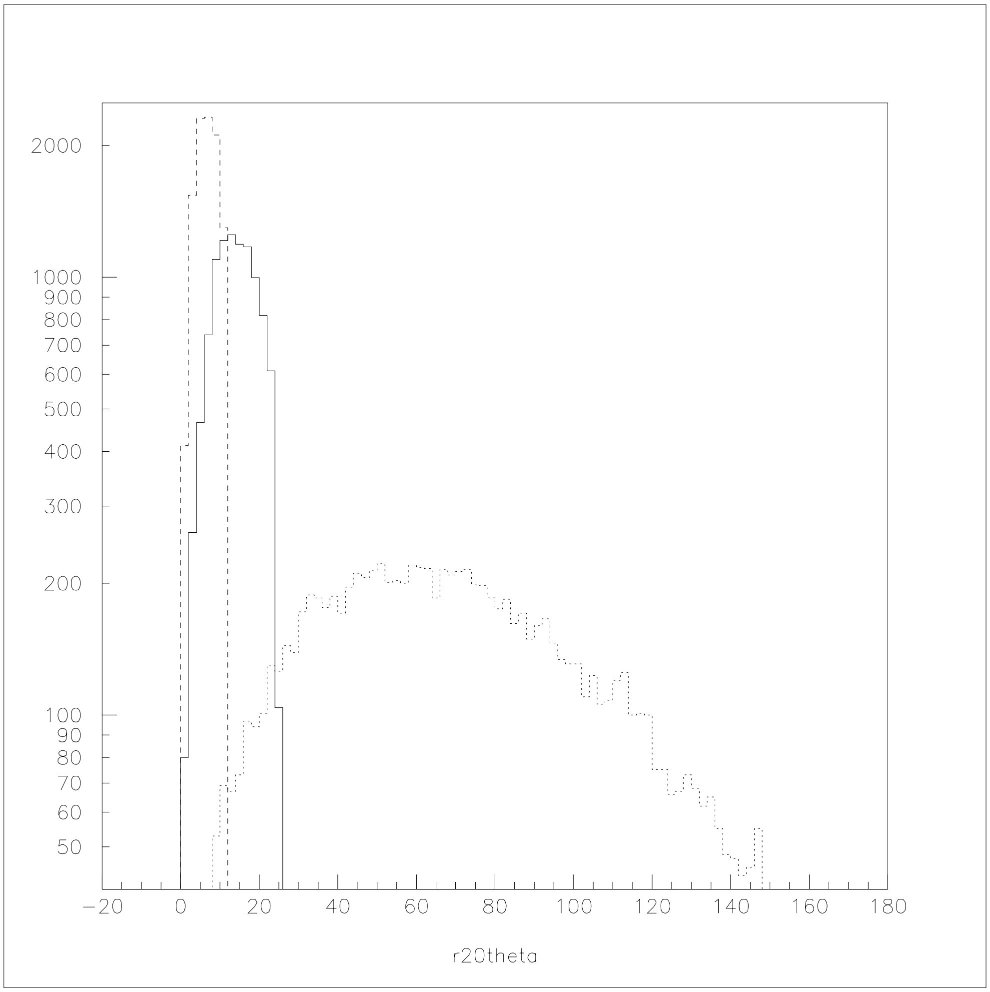

Fig. 6 Monte-carlo simulation of the angular distribution of counts from decays of the excited state in ^{19}Ne at 4.033MeV populated via the d(^{18}Ne,^{19}Ne*)p reaction as a function of the laboratory angle. ^{19}Ne* products (dotted line). Moreover, the angular ranges for ^{15}O (dashed line) and α particles (solid line) that originated in the decays from the excited ^{19}Ne* nuclei are given.

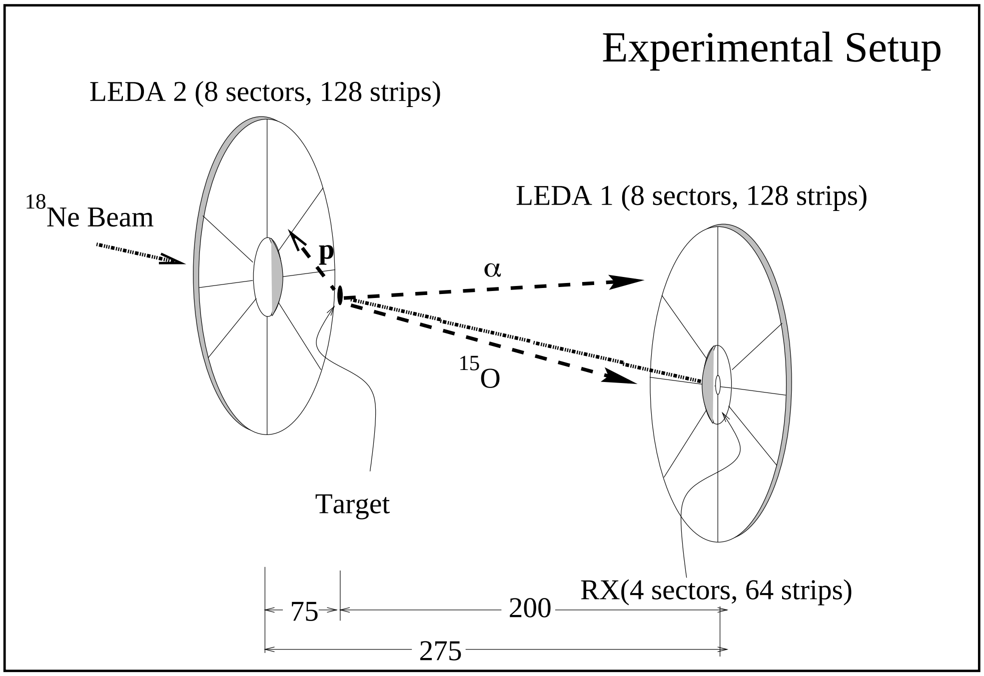

Fig. 7 Sketch of the proposed experimental set-up. The TUDA scattering chamber housing the set-up is not shown. The angular ranges covered are 2 - 10 deg (RX) 14 - 33 deg (LEDA 1) and 120 - 150 deg (LEDA 2), respectively.

Include publications in refereed journal over at least the previous 5 years.

1. Nucl.Instrum.Methods Phys.Res. A425, 1 (1999) W.Bradfield-Smith, T.Davinson, A.Di Pietro, A.M.Laird, A.N.Ostrowski, A.C.Shotter, P.J.Woods, S.Cherubini, W.Galster, J.S.Graulich, P.Leleux, L.Michel, A.Ninane, J.Vervier, J.Gorres, M.Wiescher, J.Rahighi, J.Hinnefeld *Investigation of (alpha,p) Reactions using a Radioactive Beam*, Nucl.Instrum.Methods Phys.Res. A425, 1 (1999).
2. Phys.Rev. C59, 3402 (1999) W.Bradfield-Smith, T.Davinson, A.Di Pietro, A.M.Laird, A.N.Ostrowski, A.C.Shotter, P.J.Woods, S.Cherubini, W.Galster, J.S.Graulich, P.Leleux, L.Michel, A.Ninane, J.Vervier, J.Gorres, M.Wiescher, J.Rahighi, J.Hinnefeld *Breakout from the Hot CNO Cycle via the 18Ne(alpha,p)21Na Reaction* Phys.Rev. C59, 3402 (1999)
3. A.Lepine-Szily, J.M.Oliveira, Jr., A.N.Ostrowski, H.G.Bohlen, R.Lichtenthaler, A.Blazevic, C.Borcea, V.Guimaraes, R.Kalpakchieva, V.Lapoux, M.MacCormick, F.Oliveira, W.von Oertzen, N.A.Orr, P.Roussel-Chomaz, Th.Stolla, J.S.Winfield *Study of Excited Levels of the Unbound Nucleus 11N*, Acta Phys.Pol. B30, 1441 (1999).
4. R.Raabe, A.Piechaczek, A.Andreyev, D.Baye, W.Bradfield-Smith, S.Cherubini, T.Davinson, P.Descouvemont, A.Di Pietro, W.Galster, M.Huyse, A.M.Laird, J.McKenzie, W.F.Mueller, A.Ostrowski, A.Shotter, P.Van Duppen, A.Wohr *Elastic 2n-Transfer in the 4He(6He,6He)4He Scattering*, Phys.Lett. 458B, 1 (1999).
5. W.Trinder, J.C.Angelique, R.Anne, J.Aysto, C.Borcea, J.M.Daugas, D.Guillemaud-Mueller, S.Grevy, R.Grzywacz, A.Jokinen, M.Lewitowicz, M.J.Lopez, F.de Oliveira, A.N.Ostrowski, T.Siiskonen, M.G.Saint-Laurent *beta-Decay of 35Ca*, Phys.Lett. 459B, 67 (1999).
6. A.V.Belozyorov, R.Kalpakchieva, Yu.E.Penionzhkevich, Z.Dlouhy, S.Piskor, J.Vincour, H.G.Bohlen, M.von Lucke-Petsch, A.N.Ostrowski, D.V.Alexandrov, E.Yu.Nikolsky, B.G.Novatsky, D.N.Stepanov *Spectroscopy of 13Be*, Nucl.Phys. A636, 419 (1998).
7. H.G.Bohlen, W.von Oertzen, R.Kalpakchieva, A.Blazevic, B.Gebauer, S.M.Grimes, A.Lepine-Szily, T.N.Massey, W.Mittig, A.N.Ostrowski, J.M.Oliveira, P.Roussel-Chomaz, S.Thummerer, M.Wilpert *Nuclear Structure Studies of Bound and Unbound States in Drip-Line Nuclei*, Nuovo Cim. 111A, 841 (1998).
8. W.Bradfield-Smith, T.Davinson, A.Di Pietro, A.M.Laird, A.N.Ostrowski, A.C.Shotter, P.J.Woods, S.Cherubini, W.Galster, J.S.Graulich, P.Leleux, L.Michel, A.Ninane, J.Vervier, J.Gorres, M.Wiescher, J.Rahighi, J.Hinnefeld *Break-Out from the Hot CNO Cycle via 18Ne(alpha,p)21Na*, Proc.Intern.Symposium on Nuclear Astrophysics, Nuclei in the Cosmos V, Volos, Greece, July 6-11, 1998, N.Prantzos, S.Harissopulos, Eds., Editions Frontieres, Paris, p.419 (1998).
9. J.M.Casandjian, W.Mittig, A.Pakou, N.Alamanos, G.Auger, F.Auger, M.Chartier, D.Cortina-Gil, V.Fekou-Youmbi, B.Fernandez, A.Gillibert, A.Lepine, M.MacCormick, A.Ostrowski, P.Roussel-Chomaz, J.L.Sida *Compound Nuclear Lifetimes at High Excitation Energies Via a New Statistical Fluctuation Method*, Phys.Lett. 430B, 43 (1998).

10. M.Chartier, W.Mittig, N.A.Orr, J.-C.Angelique, G.Audi, J.-M.Casandjian, A.Cunsolo, C.Donzaud, A.Foti, A.Lepine-Szily, M.Lewitowicz, S.Lukyanov, M.Mac Cormick, D.J.Morrissey, A.N.Ostrowski, B.M.Sherrill, C.Stephan, T.Suomijarvi, L.Tassan-Got, D.J.Vieira, A.C.C.Villari, J.M.Wouters *The Masses of 70,71Se*, Nucl.Phys. A637, 3 (1998).

11. A.M.Laird, A.N.Ostrowski, A.C.Shotter, M.Aliotta, F.Cappuzzello, S.Cherubini, A.Cunsolo, T.Davinson, A.Di Pietro, P.Figuera, W.Galster, J.S.Graulich, P.Leleux, L.Michel, A.Musumarra, A.Ninane, C.Spitaleri, A.Tumino, J.Vervier, P.J.Woods *The d(18Ne,19Ne*)p Reaction: A way to measure 15O(alpha,gamma) ?* Proc.Intern.Symposium on Nuclear Astrophysics, Nuclei in the Cosmos V, Volos, Greece, July 6-11, 1998, N.Prantzos, S.Harissopulos, Eds., Editions Frontieres, Paris, p.415 (1998).

12. A.Lepine-Szily, J.M.Oliveira, Jr., A.N.Ostrowski, H.G.Bohlen, R.Lichtenthaler, A.Blazevic, C.Borcea, V.Guimaraes, R.Kalpakchieva, V.Lapoux, M.MacCormick, F.Oliveira, W.von Oertzen, N.A.Orr, P.Roussel-Chomaz, Th.Stolla, J.S.Winfield *Spectroscopy of the Unbound Nucleus 11N by the 12C(14N,15C)11N Transfer Reaction*, Phys.Rev.Lett. 80, 1601 (1998).

13. M.Lewitowicz, W.Trinder, M.Bhattacharya, E.G.Adelberger, J.C.Angelique, R.Anne, J.Aysto, C.Borcea, J.M.Daugas, C.Donzaud, A.Garcia, S.Grevy, R.Grzywacz, D.Guillemaud-Mueller, A.Jokinen, N.I.Kaloskamis, S.Leenhardt, M.J.Lopez, A.C.Mueller, F.de Oliveira, A.Ostrowski, F.Pougheon, M.G.Saint-Laurent, T.Siiskonen, O.Sorlin, H.E.Swanson *Beta-Decay of Light Nuclei Close to the Proton Drip-Line: 40Ti and 35Ca*, Nuovo Cim. 111A, 835 (1998).

14. G.Neyens, N.Coulier, S.Teughels, S.Ternier, K.Vyvey, R.Coussement, D.L.Balabanski, J.M.Casandjian, M.Chartier, M.D.Cortina-Gil, M.Lewitowicz, W.Mittig, A.N.Ostrowski, P.Roussel-Chomaz, N.Alamanos, A.Lepine-Szily, W.Rogers *Quadrupole and Magnetic Moment Measurements on Spin-Aligned Projectile Fragments*, Acta Phys.Hung.N.S. 7, 101 (1998).

15. F.Nuoffer, G.Bartnitzky, H.Clement, A.Blazevic, H.G.Bohlen, B.Gebauer, W.von Oertzen, M.Wilpert, T.Wilpert, A.Lepine-Szily, W.Mittig, A.N.Ostrowski, P.Roussel-Chomaz *The Equation of State for Cold Nuclear Matter as Seen in Nucleus-Nucleus Scattering.* Nuovo Cim. 111A, 971 (1998)

16. A.N.Ostrowski, A.C.Shotter, W.Bradfield-Smith, A.M.Laird, A.di Pietro, T.Davinson, S.Morrow, P.J.Woods, S.Cherubini, W.Galster, J.S.Graulich, P.Leleux, L.Michel, A.Ninane, J.Vervier, M.Aliotta, C.Cali, F.Cappuzzello, A.Cunsolo, C.Spitaleri, J.Gorres, M.Wiescher, J.Rahighi, J.Hinnefeld *Low-Energy Radioactive Ion Beam Induced Nuclear Reactions*, J.Phys.(London) G24, 1553 (1998).

17. O.Sorlin, V.Borrel, S.Grevy, D.Guillemaud-Mueller, A.C.Mueller, F.Pougheon, W.Bohmer, K.-L.Kratz, T.Mehren, P.Moller, B.Pfeiffer, T.Rauscher, M.G.Saint-Laurent, R.Anne, M.Lewitowicz, A.Ostrowski, T.Dorfler, W.-D.Schmidt-Ott *First Beta-Decay Studies of the Neutron-Rich Isotopes 53-55Sc and 56-59V* , Nucl.Phys. A632, 205 (1998).

18. H.G.Bohlen, W.von Oertzen, Th.Stolla, R.Kalpakchieva, B.Gebauer, M.Wilpert, Th.Wilpert, A.N.Ostrowski, S.M.Grimes, T.N.Massey *Study of Weakly Bound and*

Unbound States of Exotic Nuclei with Binary Reactions, Nucl.Phys. A616, 254c (1997).

19. N.Coulier, G.Neyens, S.Ternier, K.Vyvey, S.Michiels, R.Coussement, D.L.Balabanski, J.M.Casandjian, M.Chartier, M.D.Cortina-Gil, M.Lewitowicz, W.Mittig, A.N.Ostrowski, P.Roussel-Chomaz, N.Alamanos, A.Lepine-Szily *Direct Determination of the Alignment of Projectile Fragments from a beta-Anisotropy Level Mixing Resonance (LMR) Measurement*, Acta Phys.Pol. B28, 407 (1997).

20. V.Fekou-Youmbi, J.L.Sida, N.Alamanos, W.Mittig, F.Auger, D.Bazin, C.Borcea, C.Cabot, X.Charlot, A.Cunsolo, A.Foti, A.Gillibert, N.Lecesne, A.Lepine, M.Lewitowicz, R.Liguori-Neto, F.Marie, C.Mazur, A.Mougeot, S.Ottini, E.Pollacco, A.Ostrowski, M.Riallot, P.Roussel-Chomaz, C.Volant, Y.Y.Feng *Unusual Behaviour of Fusion-Fission at Barrier Energies for a Neutron-Rich Halo Nucleus*, J.Phys.(London) G23, 1259 (1997).

21. R.Grzywacz, R.Anne, G.Auger, C.Borcea, J.M.Corre, T.Dorfler, A.Fomichov, S.Grevy, H.Grawe, D.Guillemaud-Mueller, M.Huyse, Z.Janas, H.Keller, M.Lewitowicz, S.Lukyanov, A.C.Mueller, N.Orr, A.Ostrowski, Yu.Penionzhkevich, A.Piechaczek, F.Pougheon, K.Rykaczewski, M.G.Saint-Laurent, W.D.Schmidt-Ott, O.Sorlin, J.Szerypo, O.Tarasov, J.Wauters, J.Zylicz *New mu s Isomers in T(z) = 1 Nuclei Produced in the 112Sn(63A MeV) + (nat)Ni Reaction* , Phys.Rev. C55, 1126 (1997).

22. W.Mittig, M.Chartier, J.C.Angelique, G.Audi, J.M.Casandjian, A.Cunsolo, C.Donzaud, M.Chabert, J.Ferme, L.K.Fifield, A.Foti, A.Gillibert, A.Lepine-Szily, M.Lewitowicz, S.Lukyanov, M.Mac Cormick, D.J.Morrissey, M.H.Moscatello, O.H.Odland, N.A.Orr, A.Ostrowski, G.Politi, C.Spitaels, B.M.Sherrill, C.Stephan, T.Suomijarvi, L.Tassan-Got, D.J.Vieira, A.C.C.Villari, J.M.Wouters *Mass Measurements Near* $N = Z$, Nucl.Phys. A616, 329c (1997).

23. G.Neyens, N.Coulier, S.Ternier, K.Vyvey, S.Michiels, R.Coussement, D.L.Balabanski, J.M.Casandjian, M.Chartier, M.D.Cortina-Gil, M.Lewitowicz, W.Mittig, A.N.Ostrowski, P.Roussel-Chomaz, N.Alamanos, A.Lepine-Szily *Nuclear Spin Alignment and Static Moments of Light Projectile Fragments Measured with the Level Mixing Resonance (LMR) Method*, Phys.Lett. 393B, 36 (1997).

24. O.Tarasov, R.Allatt, J.C.Angelique, R.Anne, C.Borcea, Z.Dlouhy, C.Donzaud, S.Grevy, D.Guillemaud-Mueller, M.Lewitowicz, S.Lukyanov, A.C.Mueller, F.Nowacki, Yu.Oganessian, N.A.Orr, A.N.Ostrowski, R.D.Page, Yu.Penionzhkevich, F.Pougheon, A.Reed, M.G.Saint-Laurent, W.Schwab, E.Sokol, O.Sorlin, W.Trinder, J.S.Winfield *Search for 28O and Study of Neutron-Rich Nuclei Near the* $N = 20$ *Shell Closure*, Phys.Lett. 409B, 64 (1997).

25. T.Dorfler, W.-D.Schmidt-Ott, T.Hild, T.Mehren, W.Bohmer, P.Moller, x B.Pfeiffer, T.Rauscher, K.-L.Kratz, O.Sorlin, V.Borrel, S.Grevy, x D.Guillemaud-Mueller, A.C.Mueller, F.Pougheon, R.Anne, M.Lewitowicz, x A.Ostrowsky, M.Robinson, M.G.Saint-Laurent x *Neutron-Rich Isotopes 54-57Ti*, Phys.Rev. C54, 2894 (1996).

26. G.Bartnitzky, A.Blazevic, H.G.Bohlen, J.M.Casandjian, M.Chartier, H.Clement, B.Gebauer, A.Gillibert, Th.Kirchner, D.T.Khoa, A.Lepine-Szily, W.Mittig, W.von

Oertzen, A.N.Ostrowski, P.Roussel-Chomaz, J.Siegler, M.Wilpert, Th.Wilpert *Model-Unrestricted Nucleus-Nucleus Scattering Potentials from Measurement and Analysis of 16O + 16O Scattering*, Phys.Lett. 365B, 23 (1996).

27. Th.Stolla, H.G.Bohlen, B.Gebauer, S.M.Grimes, R.Kalpakchieva, T.N.Massey, W.von Oertzen, A.N.Ostrowski, M.Wilpert, Th.Wilpert *Spectroscopy of Excited States of 8He*, Z.Phys. A356, 233 (1996)

28. H.G.Bohlen, B.Gebauer, Th.Kirchner, M.von Lucke-Petsch, W.von Oertzen, A.N.Ostrowski, Ch.Seyfert, Th.Stolla, M.Wilpert, Th.Wilpert, S.M.Grimes, T.N.Massey, R.Kalpakchieva, Y.E.Penionzhkevich, D.V.Alexandrov, I.Mukha, A.A.Ogloblin, C.Detraz *Study of Light Neutron-Rich Nuclei with 14C-Induced Reactions*, Nucl.Phys. A583, 775c (1995).

29. H.G.Bohlen, R.Kalpakchieva, D.V.Aleksandrov, B.Gebauer, S.M.Grimes, T.Kirchner, M.von Lucke-Petsch, T.N.Massey, I.Mukha, W.von Oertzen, A.A.Ogloblin, A.N.Ostrowski, C.Seyfert, T.Stolla, M.Wilpert, T.Wilpert *Spectroscopy of Excited States of 11Li*, Z.Phys. A351, 7 (1995).

30. D.T.Khoa, W.von Oertzen, H.G.Bohlen, G.Bartnitzky, H.Clement, Y.Sugiyama, B.Gebauer, A.N.Ostrowski, Th.Wilpert, M.Wilpert, C.Langner *Equation of State of Cold Nuclear Matter from Refractive 16O + 16O Elastic Scattering*, Phys.Rev.Lett. 74, 34 (1995).

31. M.Leino, J.Aysto, T.Enqvist, A.Jokinen, M.Nurmia, A.Ostrowski, W.H.Trzaska, J.Uusitalo, K.Eskola *Research on Heavy Elements Using the JYFL Gas-Filled Recoil Separator RITU*, Acta Phys.Pol. B26, 309 (1995).

32. M.Leino, J.Aysto, T.Enqvist, P.Heikkinen, A.Jokinen, M.Nurmia, A.Ostrowski, W.H.Trzaska, J.Uusitalo, K.Eskola, P.Armbruster, V.Ninov *Gas-Filled Recoil Separator for Studies of Heavy Elements*, Nucl.Instrum.Methods Phys.Res. B99, 653 (1995).

33. W.von Oertzen, H.G.Bohlen, B.Gebauer, M.von Lucke-Petsch, A.N.Ostrowski, Ch.Seyfert, Th.Stolla, M.Wilpert, Th.Wilpert, D.V.Alexandrov, A.A.Korsheninnikov, I.Mukha, A.A.Ogloblin, R.Kalpakchieva, Y.E.Penionzhkevich, S.Piskor, S.M.Grimes, T.N.Massey *Nuclear Structure Studies of Very Neutron-Rich Isotopes of 7-10He, 9-11Li and 12-14Be Via Two-Body Reactions*, Nucl.Phys. A588, 129c (1995).

34. Phys.Lett. 338B, 13 (1994) A.N.Ostrowski, H.G.Bohlen, B.Gebauer, S.M.Grimes, R.Kalpakchieva, Th.Kirchner, T.N.Massey, W.von Oertzen, Th.Stolla, M.Wilpert, Th.Wilpert *Spectroscopy of 10He*, Phys.Lett. 338B, 13 (1994).