RIA Summer School '06
Monday Talks

Time	Title
19:30	Gamma-ray spectroscopy of the doubly magic nucleus ^{56}Ni (Johansson et al.)
19:40	Mirror Symmetry in the Upper fp Shell (Andersson et al.)
19:50	T=1 and T=0 states in the N=Z=43 nucleus, ^{86}Tc (Garnsworthy, et. al.)
20:00	Rp-process studies with the Canadian Penning Trap mass spectrometer (Fallis, et. al.)
20:10	Gamma-ray Analysis for Precision Measurements (Park, et. al.)
20:20	GEANT4 code for simulations of a scintillating β-detector and its application to efficiency calibration (Golovko, et. al.)
20:30	Study of the β-decay of ^{11}Li at ISAC/TRIUMF (Mattoon, et. al.)
20:40	Sensitivity of soft vibrational modes on quadrupole deformations in ^{32}Mg and ^{34}Mg (Yoshida, et. al.)

Gamma-ray spectroscopy of the doubly magic nucleus ^{56}Ni

E. K. Johansson[1], D. Rudolph[1], J. Ekman[1,a], C. Fahlander[1], C. Andreoiu[1,b], M.A. Bentley[2,c], M. P. Carpenter[3], R.J. Charity[4], R.M. Clark[5], P. Fallon[5], R. V. F. Janssens[3], F.G. Kondev[3], T.L. Khoo[3], T. Lauritsen[3], A.O. Macchiavelli[5], W. Reviol[4], D. G. Sarantites[4], D. Seweryniak[3], C.E. Svensson[5], and S. J. Williams[2,d]

[1] *Department of Physics, Lund University, S–22100 Lund, Sweden*
[2] *School of Chemistry and Physics, Keele University, Keele, Staffordshire ST5 5BG, United Kingdom*
[3] *Physics Division, Argonne National Laboratory, Argonne, IL 60439, U.S.A.*
[4] *Chemistry Department, Washington University, St. Louis, MO 63130, U.S.A.*
[5] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, U.S.A.*
[a] *Present address: Malmö högskola, S-20506 Malmö, Sweden*
[b] *Present address: Department of Physics, University of Guelph, Guelph, Ontario, Canada N1G 2W1*
[c] *Present address: Department of Physics, University of York, Heslington, York, YO10 5DD, United Kingdom and*
[d] *Present address: School of Chemistry and Physics, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom*

Fundamental building blocks within nuclear structure are the experimentally observed shell gaps associated with the magic numbers, which are very well reproduced by the nuclear shell model. In my research I have studied the doubly magic $N = Z$ nucleus ^{56}Ni with two experiments using fusion-evaporation reactions; ^{40}Ca(^{28}Si,3α)^{56}Ni at a beam energy of 122 MeV and ^{28}Si(^{32}S,2p2n)^{56}Ni at 130 MeV. To find the excited states in ^{56}Ni, the gamma rays were detected by the Ge-detector array Gammasphere in coincidence with evaporated particles detected by the charged particle detector system Microball and a neutron detector array. The results include a significantly extended level scheme of ^{56}Ni, which is compared to large scale shell-model calculations in the fp shell. The experimental and theoretical results agree to a large extent, with one notable and surprising exception; the theoretical model fails to predict the proper sequence of the yrast and yrare 8^+ states.

Mirror Symmetry in the Upper fp Shell

L-L. Andersson[1], D. Rudolph[1], J. Ekman[1], C. Fahlander[1], E.K. Johansson[1]
R. du Rietz[1], C. J. Gross[2], P. A. Hausladen[2], D. C. Radford[2], G. Hammond[3]
[1] *Department of Physics, Lund University, S–22100 Lund, Sweden*
[2] *Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830 and*
[3] *Department of Physics, University of York, York YO10 5DD, United Kingdom*

My research deals with the study of isospin symmetry by means of γ-ray spectroscopic nuclear structure studies of mirror nuclei. The data set I am currently analysing is from a fusion-evaporation experiment performed in August 2003 at the Oak-Ridge National Laboratory. The reaction, ^{40}Ca + ^{24}Mg at 104 MeV beam energy, was used to produce the two mirror nuclei $^{61}_{31}$Ga$_{30}$ and $^{61}_{30}$Zn$_{31}$. The experimental set-up comprised the Ge-array CLARION, a recoil mass spectrometer and, in its focal plane, an ionisation chamber. This set-up allowed γ rays from CLARION to be detected in coincidence with the the detection of recoils in the focal plane at the end of the Recoil Mass Spectrometer, providing the possibility of recoil-γ-γ analysis of the transitions. Five excited states have been observed, for the first time, in the ^{61}Ga isotope, and three of these form a cascade. The decay scheme of ^{61}Zn has also been extended using data from the Oak-Ridge experiment. Information on the excited states in both mirror nuclei provides the possibility of comparing and exploring the forces acting in the nucleus. The experimental results have also been compared to predictions from different sets of large scale shell-model calculations.

T=1 and T=0 states in the N=Z=43 nucleus, ^{86}Tc*

A. B. Garnsworthy[1,2], P. H. Regan[1], S. Pietri[1], D. Rudolph[3], Zs. Podolyák[1], S. J. Steer[1], F. Becker[4], P. Bednarczyk[4], J. Gerl[4], M. Górska[4], H. Grawe[4], I. Kojouharov[4], H. Schaffner[4], H. J. Wollersheim[4], J. Grębosz[5,4], G. Benzoni[6], B. Blank[7], C. Brandau[1], A. M. Bruce[8], L. Caceres[4,9], F. Camera[6], W. N. Catford[1], I. J. Cullen[1], Zs. Dombrády[10], P. Doornenbal[4], E. Estevez[11], H. Geissel[4], W. Gelletly[1], A. Heinz[2], R. Hoischen[3], G. Ilie[12], J. Jolie[12], G. A. Jones[1], A. Jungclaus[9], A. Kelic[4], M. Kmiecik[5], F. G. Kondev[13], T. Kurtukian-Nieto[11], N. Kurz[4], S. Lalkowski[14], Z. Liu[1], A. Maj[5], S. Myalski[5], F. Montes[4], M. Pfützner[15], T. Saito[4], T. Shizuma[1,16], A. J. Simons[1], S. Schwertel[17], S. Tachenov[4], P. M. Walker[1], E. Werner-Malento[4,15], O. Wieland[6]

[1] *Department of Physics, University of Surrey, Guildford, GU2 7XH, UK*
[2] *WNSL, Yale University, 272 Whitney Avenue, New Haven, CT, 06520, USA*
[3] *Department of Physics, Lund University, S-22100, Lund, Sweden*
[4] *GSI, Planckstrasse 1, D-64291, Darmstadt, Germany*
[5] *The Henryk Niewodniczański Institute of Nuclear Physics, PL-31-342, Kraków, Poland*
[6] *Universitá degli Studi di Milano and INFN sezione di Milano, I-20133, Milano, Cmerino, Italy*
[7] *CENBG, le Haut Vigneau, F-33175, Gradignan Cedex, France*
[8] *School of Engineering, University of Brighton, Brighton, BN2 4GJ, UK*
[9] *Depertmento di Teórica, Univeridad Autonoma de Madrid, E-28049, Madrid, Spain*
[10] *Institute for Nuclear Research, H-4001, Debrecen, Hungary*
[11] *Universidad de Santiago de Compostela, E-15706, Santiago de Campostela, Spain*
[12] *IKP, Universität zu Köln, D-50937, Köln, Germany*
[13] *Nuclear Engineering Division, Argonne National Laboratory, Argonne, IL-60439, USA*
[14] *Faculty of Physics, University of Sofia "St. Kliment Ohridsk" Sofia, Bulgaria*
[15] *IEP, Warsaw University, Hoża 69, PL-00-681, Poland*
[16] *Japan Atomic Energy Research Institute, Kyoto, 619-0215, Japan and*
[17] *Physik Department E12, Technische Universität München, Garching, Germany*

The low-lying structure of ^{86}Tc has been studied using isomer-decay spectroscopy at GSI in the first experiment of the Stopped-Beam phase within the Rare ISotope INvestigation at GSI (RISING) campaign. Following projectile fragmentation of a 750 MeV/u beam of ^{107}Ag, reaction products were separated and unambiguously identified using the FRagment Separator (FRS) in combination with its ancillary detectors. The ions were made to stop in a plastic stopper at the final focus of the FRS in the centre of the Stopped RISING γ-ray spectrometer. This high-efficiency, high-granularity array consists of 15 germanium cluster detectors in a compact configuration which provides a full photopeak efficiency in excess of 15% at 1.3 MeV. Internal decay of the previously identified [1] microsecond isomer in ^{86}Tc was confirmed with the addition of two previously unobserved γ-rays which help to determine the excitation energy and spin of the isomeric state. As in other heavy odd-odd N=Z nuclei a notably lower density of states below 1 MeV excitation energy compared with neighbouring odd-odd nuclei away from the N=Z line [2] is observed with the lowest T=0 state identified in the preliminary analysis being a $J^{\pi}=3^{+}$ state located 1176 keV above the T=1 [3] groundstate. Results from this experiment will be discussed along with assignments of structure made from shell model calculations and systematics of N=Z nuclei.

[1] C. C. Chandler *et al.*, Phys. Rev. C 61, 044309 (2000)
[2] D. J. Jenkins, *et al*, Phys. Rev. C 65, 064307 (2002)
[3] C. Longour, *et al*, Phys. Rev. Lett. 81, 3337 (1998)

* This work was partially supported by the EPSRC (UK) and the U. S. Department of Energy under grants DE-FG02-91ER-40609 and W-31-109-ENG-38. ABG would also like to acknowledge financial support from Nexia Solutions Limited, a subsidiary of BNFL.

Rp-process studies with the Canadian Penning Trap mass spectrometer

J. Fallis [1], J. A. Clark [6], G. Savard [2], K. S. Sharma [1], R. C. Barber [1], F. Buchinger[3], S. Caldwell [8], J. E. Crawford [3], S. Gulick [3], A. A. Hecht [2], D. Lascar [7], J.K.P. Lee [3], A. F. Levand [2], N.D. Scielzo [2], R. Segel [7], D. Seweryniak [2], H.P. Sharma [1,2], G. D. Sprouse [4], I. Tanihata [2], Y. Wang [1], B.J. Zabransky [2]

[1]Department of Physics & Astronomy, University of Manitoba, Winnipeg, MB R3T 2N2 Canada
[2]Physics Division, Argonne National Laboratory, Argonne, IL 60439 USA
[3]Department of Physics, McGill University, Montreal, PQ H3A 2T8 Canada
[4]Physics Department, SUNY, Stony Brook University, Stony Brook, NY 11794 USA
[5]Cyclotron Institute, Texas A&M University, College Station, Texas 77843 USA
[6]Yale University, New Haven, Connecticut 06520, USA
[7]Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208 USA
[8]Department of Physics, University of Chicago, IL 60637 USA

The Canadian Penning Trap (CPT) mass spectrometer located at Argonne National Laboratory is involved in measuring the masses of stable and unstable isotopes for various purposes. One of the main areas of study involves mass measurements which provide proton capture Q-values for isotopes along the astrophysical rapid proton (rp) process. There are two areas of this process currently being studied with the CPT: the midpoint isotopes, many of which have never been measured experimentally and the endpoint of the process where the reaction chain is terminated due to the onset of alpha-decay in tellurium. Current measurements and future plans will be discussed.

Gamma-ray Analysis for Precision Measurements

H.I. Park, J.C. Hardy, V. Golovko, V.E. Iacob, N. Nica, and J. Goodwin
Cyclotron Institute, Texas A&M University, College Station, TX77843

High-precision measurements of the *ft* values for superallowed beta-decay transitions are an important element to test the standard model description of weak interactions. As a part of this study, a technique has been developed for calibrating a HPGe detector with an accuracy of 0.2% from 50keV to 1400keV [1] and it is essential to apply this calibration to experimentally measured spectra with a consistent spectrum analysis. For this presentation, the effects of extremely small variations on peak shapes obtained from a ^{60}Co source will be discussed in terms of high-precision measurements.

[1] R.G. Helmer *et. al.* Nucl. Instr. and Meth. A 511 (2003) 360.

GEANT4 code for simulations of a scintillating β-detector and its application to efficiency calibration

V.V. Golovko, V.E. Iacob, J.C. Hardy,[1]

[1] *Cyclotron Institute, Texas A&M University, College Station, TX 77843-3366, USA*

Precise β^+-branching-ratio measurements are required to determine ft-values as a part of our program to test the Standard Model via unitarity of the Cabibbo-Kobayashi-Moskava matrix. For the measurements to be useful in this test, their precision must be close to 0.1% [1]. This is a particularly demanding requirement for β-decay branching-ratio experiments. In a branching-ratio measurement, we typically collect a radioactive species in mylar tape, and then move the tape to a shielded counting station, where the sample is positioned between a thin scintillator used to detect β-particles, and a high-volume HPGe detector for γ-rays. The signals from both detectors are recorded for all events in which there is a $\beta - \gamma$ coincidence. Although we obtain the β branching ratio from the absolute intensity of the coincidence γ rays, the relative efficiency of the β-detector as a function of β energy is crucial to our achieving a precise result since different γ-ray peaks correspond to β-transitions with different end-point energies.

We have studied our β-detector response function using Monte Carlo calculations performed by GEANT4 code. Since there are always question about the validity of any particular simulation code, the simulated results were compared to measured β-spectra from various standard β-sources, as well as with Monte Carlo simulated β-response functions obtained with the EGS-code [2].

References

[1] J. C. Hardy and I. S. Towner. *Physical Review C*, 71(5):055501, 2005.

[2] V. E. Iacob, J. C. Hardy, and N. Nica. *BAPS 49*, no 6, p J9 111, 2004.

Study of the β-decay of ^{11}Li at ISAC/TRIUMF

C.M. Mattoon,[1] F. Sarazin,[1] C. Andreoiu,[2] A. Andreyev,[3] R.A.E. Austin,[4] G.C. Ball,[3] R.S. Chakrawarthy,[3] D. Cross,[5] E.S. Cunningham,[3,6] J. Daoud,[3,6] P.E. Garrett,[7] G.F. Grinyer,[7] G. Hackman,[3] D. Melconian,[3,8] A.C. Morton,[3] C. Pearson,[3] J. Ressler,[5] J. Schwarzenberg,[9] M.B. Smith,[3] and C.E. Svensson[7]

[1] *Department of Physics, Colorado School of Mines, Golden, CO 80401*
[2] *Department of Physics, University of Guelph, Guelph ON, Canada N1G 2W1*
[3] *TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T 2A3*
[4] *Department of Physics and Astronomy, Saint Mary's University, Halifax, NS, Canada B3H 3C3*
[5] *Department of Chemistry, Simon Fraser University, Burnaby BC, Canada V5A 1S6*
[6] *Department of Physics, University of Surrey, Guildford, Surrey, United Kingdom GU2 7XH*
[7] *Department of Physics, University of Guelph, Guelph, ON, Canada N1G 2W1*
[8] *Department of Physics, Simon Fraser University, Burnaby BC, Canada V5A 1S6*
[9] *Department of Nuclear Physics, University of Vienna, Waehringerstrasse 17, Vienna, Austria 1090*

The β-decay of the halo nucleus ^{11}Li was investigated at ISAC/TRIUMF with the 8π spectrometer, an array of 20 Compton-suppressed high-purity germanium detectors. In August 2002, a beam of about a thousand ^{11}Li atoms per socond was delivered and implanted at the center of the 8π. The gamma spectrum reselting from the β-decay of ^{11}Li shows remarkable features, namely Doppler-broadened line shapes arising from the decay of the excited states of ^{10}Be, populated by β-delayed one-neutron emission. A Monte Carlo simulation was developed to analyze these complex line shapes, from which it was possible to extract the lifetime of these excited states in ^{10}Be and some information about the neutron emitting states in ^{11}Be [1]. Disagreements were however observed with an experiment using a polarized ^{11}Li beam and time-of-flight neutron detectors [2]. Following the development of a more intense ^{11}Li beam at ISAC, the experiment was recently repeated with an enhanced experimental setup, comrising the 8π and Sceptar, a plastic scintillating array located in the inner volume of the 8π. The higher ^{11}Li yield and the capability of taking data in β-γ coincidences lead to higher quality line shapes, as seen in the figure below. The analysis of those line shapes should help resolve the discrepancies observed with [2] and possibly lead to new insights in the β-decay of ^{11}Li.

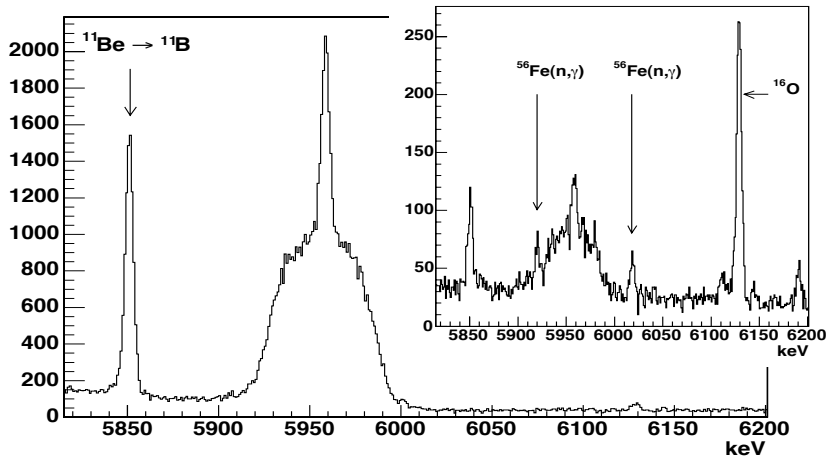

FIG. 1: Line shape of the ∼5958keV transition as observed in the recent experiment compared to the first one (inset). The overall lineshape quality is improved both by the higher statistics obtained and by the removal of transitions uncorrelated with the beam implantation using β-γ coincidences.

[1] F. Sarazin et al., Phys. Rev. C 70 (2004) 031302R
[2] Y. Hirayama et al., Phys.Lett. B 611 (2005) 239

Sensitivity of soft vibrational modes on quadrupole deformations in ^{32}Mg and ^{34}Mg

Kenichi Yoshida[1], Masayuki Yamagami[2] and Kenichi Matsuyanagi[1]

[1]*Department of Physics, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan*
[2]*Radioactive Isotope Physics Laboratory, RIKEN, Wako, Saitama 351-0198, Japan*

Presently, breaking of the N=20 spherical magic number and striking enhancements of $B(E2; 0_1^+ \to 2_1^+)$ in ^{32}Mg and ^{34}Mg are under lively discussions in connection with onset of quadrupole deformations, pairing correlations and the continuum coupling effects. In order to get clear understanding of the nature of quadrupole deformation and pairing correlations in these nuclei, it is strongly desired to explore, both experimentally and theoretically, excitation spectra of these nuclei. For this aim, we have recently constructed a new computer code which carries out deformed Quasiparticle-RPA calculations based on the coordinate-space Hartree-Fock-Bogoliubov formalism. Using this code, we made a detailed analyses of the interplay among the quadrupole particle-hole, the monopole-pairing and the quadrupole-pairing correlations in building up low-frequency vibrational excitations in neutron-rich Mg isotopes. In these systematic calculations, the deformed Woods-Saxon potential, the Skyrme-type interaction without the momentum dependent terms and the density dependent contact pairing interaction were used. The HFB equations were solved on the two-dimensional lattice consisting of the cylindrical coordinates. We are particularly interested in the question how the properties of low-frequency collective modes depend on the magnitude of static quadrupole deformation β_2 of the mean field. Thus, we carried out a systematic Quasiparticle-RPA calculation treating β_2 as a parameter and investigated how the properties of these modes change as function of β_2. Figure 1 shows the calculated excitation energies and isoscalar quadrupole (octupole) strengths for the lowest $K^\pi = 0^+$ and 2^+ (0^- and 1^-) excitation modes in ^{32}Mg and ^{34}Mg. We obtained strongly collective $K^\pi = 0^+$ modes (carrying $50 \sim 80$ W.u. in intrinsic strengths) at about 2 MeV in the $\beta_2 = 0.3 \sim 0.5$ region; they are mainly generated by neutron pair fluctuation associated with the monopole and the quadrupole pairing correlations. It was found that the quadrupole pairing significantly enhances the pair transfer strengths to these $K^\pi = 0^+$ excited states. The γ-vibrational-type collective $K^\pi = 2^+$ modes were obtained at about 3 MeV in the deformed region with $\beta_2 \geq 0.3$; they are generated by coherent two-quasiparticle excitations of neutrons and protons. It is clearly seen in Fig. 1 that the transition strengths for octupole vibrational excitations greatly increase as the quadrupole deformation grows. In the superdeformed region ($\beta_2 \sim 0.6$), the intrinsic transition strength becomes about 100 W.u. for the $K^\pi = 0^-$ mode. On the basis of these theoretical calculations, we suggest that the octupole strengths will be greatly enhanced if the ground states of ^{32}Mg and ^{34}Mg are strongly deformed.

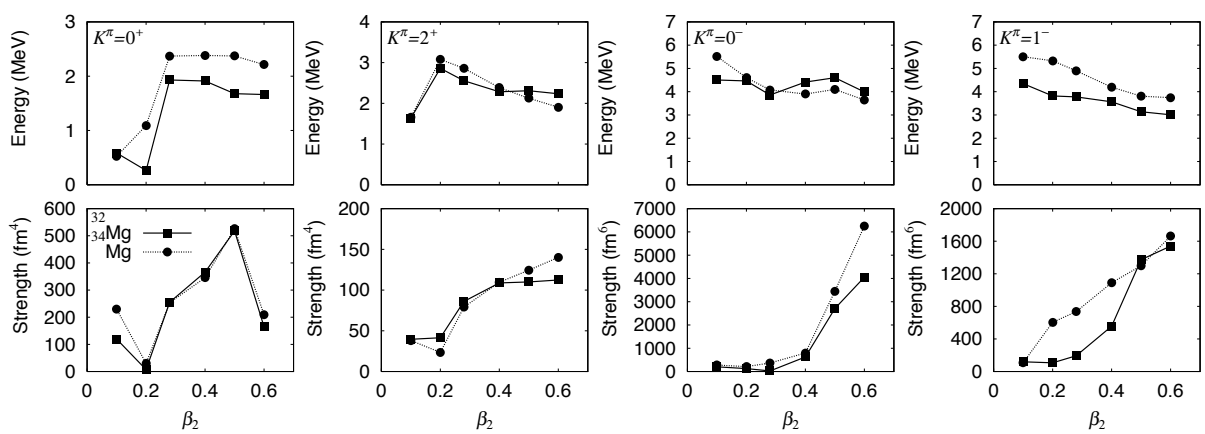

Figure 1: Excitation energies [*upper panel*] and isoscalar quadrupole (octupole) strengths [*lower panel*] for the lowest $K^\pi = 0^+$, 2^+, 0^- and 1^- excitation modes in ^{32,34}Mg, plotted as functions of the static quadrupole deformation parameter β_2 of the mean field. The filled squares and the filled circles indicate the calculated values for ^{32}Mg and ^{34}Mg, respectively.