Summary of the research program related to radionuclide metrology for the years 2007 till 2009

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http://kernphysik.univie.ac.at/

Some activities of the two research groups concentrate on the improvement and development of atomic and nuclear measuring techniques and data handling procedures for basic physics and interdisciplinary applied physics work with special emphasis on the detection of long-lived radionuclides, particularly in the very-low-level range. Nuclear-decay-counting techniques have been widely replaced by mass-spectrometric techniques with high selectivity and high sensitivity. More detailed information is also provided via the home pages given above.

Names: K. Buczak, F. Dellinger, F. Eder, O. Forstner , E. Friedl, H. Friedmann, R. Golser, J. Gröller, P. Hille, D. Imrich, J. Kühtreiber, W. Kutschera, C. Lederer, St. Lehr, J. Liebl, J. Lukas, M. Martschini, K. Melber, Ph. Müllner, E. Pak, A. Pavlik, A. Priller, F. Quinto, L. Reichart, K. Rumpelmayr, G. Schätzel, P. Steier, S. Tagesen, P. Törnström, H. Vonach, A. Wallner, F. Weninger, E. Wild, G. Winkler

Facilities, projects, tasks:

1. The tandem-accelerator mass-spectrometry facility VERA (Vienna Environmental Research Accelerator) and its use:

For details on the experimental equipment see:
http://isotopenforschung.univie.ac.at/index.php?id=1571 .
Accelerator mass spectrometry (AMS) injecting negative ions into a tandem accelerator and stripping them to positive ions is the major tool for research. With AMS, radionuclides are measured by direct atom counting; selectivity is achieved employing energy-, momentum- and velocity-selecting devices (electrostatic, magnetic, velocity and time-of-flight filters) and using ion detectors for counting, discrimination and final energy measurement. The interesting nuclides (with extremely small radioisotope-to-stable-isotope ratios in the 10^{-10} to 10^{-16} range) cannot be measured at natural levels through radioactive-decay counting, particularly for small samples in the milligram range, typically containing only 10^5 to 10^8 radionuclide atoms. Predominantly isotope ratios are measured relative to appropriate standards.

Typically, in the light-ion region atoms like ^{14}C (5.7×10^3 a) for radiocarbon dating, atmospheric science, paleoclimatic studies, ^{10}Be ($T_{1/2}=1.5\times10^6$ a) and ^{26}Al ($T_{1/2}=7.2\times10^5$ a) [both, e.g., for applications in geology, atmospheric and climate

research, in particular employing $^{26}Al/^{10}Be$ ratios], heavy long-lived radionuclides such as ^{129}I ($T_{1/2} \approx 1.6\times10^{7}$ a), ^{236}U ($T_{1/2} \approx 23\times10^{6}$ a) [in natural and anthropogenic environmental samples), ^{239}Pu (2.4×10^{4}a) [together with ^{236}U in uranium ores], ^{244}Pu ($T_{1/2} \approx 81\times10^{6}$ a) [for research on e.g. interstellar medium grains], ^{242}Pu ($T_{1/2} \approx 3.8\times10^{5}$ a) and ^{182}Hf ($T_{1/2} \approx (9\pm2)\times10^{6}$ a) [of interest in astrophysics and geophysics, requiring new isobar separation methods] are counted in natural samples with an excellent suppression of isobaric background. Also, AMS studies with ^{41}Ca and ^{60}Fe atoms were performed. Recently, Laser techniques were tried to assist isobar suppression in AMS.

Recent publications involving AMS measurements are, e.g.:

NATURAL AND ANTHROPOGENIC ^{236}U IN ENVIRONMENTAL SAMPLES,
Peter Steier, Max Bichler, L. Keith Fifield, Robin Golser, Walter Kutschera, Alfred Priller, Francesca Quinto, Stephan Richter, Michaela Srncik, Philippo Terrasi, Lukas Wacker, Anton Wallner, Gabriele Wallner, Klaus M. Wilcken, Eva Maria Wild,
Proceedings of the 9th International Conference on the Application of Accelerators in Research and Technology, Florence, Italy, September 3-7, 2007; Nucl. Instr. and Meth. **B 266** (2008) 2246-2250

AMS OF NATURAL ^{236}U AND ^{239}Pu PRODUCED IN URANIUM ORES,
K.M. Wilcken, T.T. Barrows, L.K. Fifield, S.G. Tims, P. Steier,
Nuclear Instruments and Methods **B 259** (2007) 727-732

APPLICATIONS OF A COMPACT IONIZATION CHAMBER IN AMS AT ENERGIES BELOW 1 MeV/amu,
O. Forstner, L. Michlmayr, M. Auer, R. Golser, W. Kutschera, A. Priller, P. Steier, A. Wallner,
Proceedings of the 9th International Conference on the Application of Accelerators in Research and Technology, Florence, Italy, September 3-7, 2007; Nucl. Instr. and Meth. **B 266** (2008) 2213-2216

MEASUREMENT OF THE STELLAR CROSS SECTIONS FOR THE REACTIONS $^{9}Be(n,\gamma)^{10}Be$ and $^{13}C(n,\gamma)^{14}C$ via AMS,
A. Wallner, L. Coquard, I. Dillmann, O. Forstner, R. Golser, M. Heil, F. Käppeler, W. Kutschera, A. Mengoni, M. Paul, A. Priller, P. Steier,
Journal of Physics G **35** (2008) 014018

$^{40}Ca(\alpha,\gamma)^{44}Ti$ AND THE PRODUCTION OF ^{44}Ti IN SUPERNOVAE,
C. Vockenhuber, C.O. Ouellet, L.-S. The, L. Buchmann, J. Caggiano, A.A. Chen, H. Crawford, J.M. D'Auria, B. Davids, L. Fogarty, D. Frekers, A. Hussein, D.A. Hutcheon, W. Kutschera, A.M. Laird, R. Lewis, E. O'Connor, D. Ottewell, M. Paul, M.M. Pavan, J. Pearson, C. Ruiz, G. Ruprecht, M. Trinczek, B. Wales, and A. Wallner,
Journal of Physics G **35** (2008) 014034

STUDY OF THE $^{60}Ni(n,2n)^{59}Ni$ REACTION FROM THE THRESHOLD TO 20 MeV AND THE HALF-LIFE OF ^{59}Ni,
A.Wallner, K. Knie, T. Faestermann, G. Korschinek, W. Kutschera, W. Rochow, G. Rugel, H. Vonach,
In: Proceedings of the International Conference on Nuclear Data for Science and Technology, April 22-27, 2007, Nice, France, eds., O. Bersillon, F. Gunsing, E. Bauge, R. Jacqmin, and S. Leray, EDP Sciences (2008) 1007-1010

MEASUREMENT OF THE THERMAL NEUTRON CAPTURE CROSS SECTION AND THE RESONANT INTEGRAL OF RADIOACTIVE ^{182}Hf,
C. Vockenhuber, M. Bichler, A. Wallner, W. Kutschera, I. Dillmann, F. Käppeler,
Phys. Rev. **C 77** (2008) 044608

SEARCH FOR SUPERNOVA-PRODUCED ^{60}Fe IN A MARINE SEDIMENT,
C. Fitousse, G.M. Raisbeck, K. Knie, G. Korschinek, T. Faestermann, S. Goriely, D. Lumney, M. Poutivtsev, G. Rugel, C. Waelbroeck, A. Wallner,
Physical Review Letters 101 (2008) 121101

TOWARDS MORE PRECISE ^{10}BE AND ^{36}CL DATA FROM MEASUREMENTS AT THE 10^{-14} LEVEL: INFLUENCE OF SAMPLE PREPARATION,
S. Merchel, M. Arnold, G. Aumaître, L. Benedetti, D.L. Bourlès, R. Braucher, V. Alfimov,.P.H.T. Freeman, P. Steier, A. Wallner,
Nuclear Instruments and Methods in Physics Research B 266 (2009) 4921-4926

ISOBAR SUPPRESSION IN AMS USING LASER PHOTODETACHMENT,
O. Forstner, P. Andersson, C. Diehl, R. Golser, D. Hanstorp, W. Kutschera, A. Lindahl, A. Priller, P. Steier, A. Wallner,
Proceedings of the XVth International Conference on Electromagnetic Isotope Separators and Techniques Related to their Applications, Deauville, France, June 24-29, 2007; Nucl. Instr. and Meth. **B** (2008) accepted manuscript, DOI 10.1016/j.nimb.2008.05.080

FIRST RESULTS ON ^{236}U LEVELS IN GLOBAL FALLOUT,
A. Sakaguchi, K. Kawai, P. Steier, F. Quinto, K. Mino, J. Tomita, M. Hoshi, N. Whitehead, M. Yamamoto,
Science of the Total Environment (2009) in press

THE FIRST USE OF ^{236}U IN THE GENERAL ENVIRONMENT AND NEAR A SHUT DOWN NUCLEAR POWER PLANT,
Francesca Quinto, Peter Steier, Gabriele Wallner, Anton Wallner,
Michaela Srncik, Max Bichler, Walter Kutschera, Filippo Terrasi, Antonio Petraglia, Carlo Sabbarese,
Manuscript accepted by Applied Radiation and Isotopes (2009).

Recent projects involving radiocarbon measurements are, e.g.,

THE ANTHROPOGENIC INFLUENCE ON CARBONACEOUS AEROSOL IN THE EUROPEAN BACKGROUND,
Barbara May, Dietmar Wagenbach, Samuel Hammer, Peter Steier, Hans Puxbaum, Casimiro Pio,
Tellus 61 (2009) 464-462

RADIOCARBON (^{14}C) DATING IN ARCHAEOLOGY AND OTHER FIELDS,
W. Kutschera,
In: G. Pfenning, C. Normand, J. Magill, T. Fanghänel, eds., Karlsruher Nuklidkarte, Commemoration of the 50th Anniversary, Institute for Transuranium Elements, Karlsruhe (2008) 262-267.

A unique signature to date young carbon-containing samples is utilizing the ^{14}C nuclear bomb peak due to the redistribution of $^{14}CO_2$ into the other carbon archives on Earth (biosphere, oceans) after the atmospheric Nuclear Test Ban Treaty in 1963. This signal was used, e.g., in collaboration with the Forensic Medicine Department to determine the date of death of people who died in the late 1980s, and is now intended to develop methods at VERA for ^{14}C measurements on ultra-small DNA samples originating from small regions of the human brain.

Atomic and molecular physics

The molecule H_2 (of interest in the cooling phase of the early universe) was unambiguously detected. The existence of rare exotic negatively-charged molecular ions was also studied via AMS:

IDENTIFICATION OF THE SiF_6^{2-} DIANION BY ACCELERATOR MASS SPECTROMETRY AND A FULLY RELATIVISTIC COMPUTATION OF ITS PHOTODETACHMENT SPECTRUM, H. Gnaser, R. Golser, M. Pernpointner, O. Forstner, W. Kutschera, A. Priller, P. Steier, A. Wallner, Phys. Rev. **A 77** (2008) 053203.

The AMS accelerator has also been used for PIXE measurements employing a very low-current proton beam externally:

PIXE MEASUREMENTS OF RENAISSANCE SILVERPOINT DRAWINGS AT VERA, P. Milota, I. Reiche, A. Duval, O. Forstner, H. Guicharnaud, W. Kutschera, S. Merchel, A. Priller, M. Schreiner, P. Steier, E. Thobois, A. Wallner, B. Wünschek, R. Golser, Proceedings of the 9th International Conference on the Application of Accelerators in Research and Technology, Florence, Italy, September 3-7, 2007; Nucl. Instr. and Meth. **B 266** (2008) 2279-2285

2. Other recent radionuclide measurements and evaluation methods

VERTICAL DISTRIBUTION OF ^{238}Pu, $^{239(40)}Pu$, ^{241}Am, ^{90}Sr AND ^{137}Cs IN AUSTRIAN SOIL PROFILES, M. Srncik, E. Hrnecek, P. Steier, A. Wallner, G. Wallner, P. Bossew, Radiochim. Acta 96 (2008) 733–738.

A major contribution was given to the recently completed "National Survey of Indoor Radon Concentration", a large-scale investigation on the impact of natural radioactivity on the Austrian population [H. Friedmann].

3. Work and co-operation on special reports and standard concepts, training tasks

Co-operation with the *Austrian Standards Institute* (OENORM) in fields related to radionuclide metrology (e.g., low-level measurements, Radon) is continued.

Students' training in the field of general experimental physics, quantum physics, atomic physics, nuclear physics, ion physics and radioactivity measurements is taken care of by the staff of the Isotope Research and Nuclear Physics Group.

4. Participation in international organisations dealing with radionuclide metrology

- International Committee for Radionuclide Metrology (ICRM) [G. Winkler]
- Consultative Committee for Ionizing Radiation (CCRI), Section II (Measurement of Radionuclides) at the BIPM, Sèvres, France [personal member: G. Winkler]

June 2009 Gerhard Winkler