# Summary of Nuclear Spectroscopy*

A strong activity in nuclear spectroscopy during recent years made use of the world-wide unique combination of the MP tandem with very good energy stability and the Q3D magnetic spectrograph that offers excellent energy resolution. High intensity hydrogen ions were provided by the commercial multicusp source, helium ions and polarized hydrogen ions from the home built Stern-Gerlach source with ECR ionizer [1]. As detector for light ions exclusively the 0.89 m wide proportional detector with readout of cathode strips [2] was used. Its position resolution is very good and contributes negligibly to the overall energy resolution of $1x10^{-4}$. Most of the subjects investigated where of interest within the DFG cluster of excellence 'Origin and Structure of the Universe', like for Nuclear Astrophysics, for particle physics by quantifying the first element of the quark mixing matrix or nuclear transition matrix elements relevant for neutrino-less double-β decay. It should be mentioned here that the Q3D spectrograph was as well used in applied physics for high-resolution depth profile measurements by Elastic Recoil Detection Analysis. Here two different heavy ion detectors were employed in the focal plane.

In 2013 there was a longer campaign at the MLL accelerator laboratory with four triples of the 6-fold segmented Miniball Ge-detectors [3].

MLL scientists were also heavily involved in experiments at the facilities of GSI, Darmstadt, to explore exotic nuclei. With beams from the SIS18 synchrotron reaction fragments were analyzed by the fragment separator FRS and suitable detectors along the fragments path. Decay properties of identified stopped fragments were then measured with highly sophisticated charged-particle and γ-detectors. The main focus was on nuclei in the region near the doubly magic nucleus $^{100}$Sn. And the highlight was the quantitative determination of the β-decay strength of the latter nucleus, that turned out to be the largest in the nuclidic chart. The detector systems developed in the MLL were also used to investigate decay modes of very neutron rich nuclei. This helps for understanding the r-process nucleosynthesis.

The experimental storage ring ESR at GSI is a unique tool to study β-decay modes of nuclei with no or just a few electrons. Examples are: bound-state β-decay where the electron in β-decay is not emitted into the continuum but into an atomic state, preferably the empty K-shell. This is a two-body decay, where a monoenergetic anti-neutrino is emitted, similarly as in the electron capture decay, where the emitted neutrino is monoenergetic. Also the latter process has been studied for ions with only one or two electrons in the K-shell. In such two-body decays the decay rate of ions coasting in the ESR seems not to be constant but modulated with a sinusoidal dependence. A hypothetical interpretation of this phenomenon as being due to an interference of the different possible mass eigenstates of the emitted neutrino is highly disputed.

As was shown also in an experiment at the MLL, such a behavior is not observed in an experiment, where the decaying nucleus cannot assume a sharp recoil momentum while bound in a lattice and where the final state is not stable or long-lived thus having a finite energy width.

Exotic nuclei were also studied at the Radioactive Ion Beam Facility RIBF at the RIKEN Nishina Center in Japan and reaccelerated radioactive ions at REX-ISOLDE, CERN, were used for Coulomb Excitation and transfer experiments.

As usually most of the work has been done by students:

**Diploma thesis**

Konrad Steiger, Effizienzbestimmung des Detektoraufbaus für die Zerfallsspektroskopie von $^{100}$Sn, TU München, 2009

**Master thesis**

Sebastian Reichert: Untersuchung der Multiplizität charakteristischer Röntgenstrahlung nach Fusions-prozessen schwerer Kerne mit dem MINIBALL Spektrometer, TU München, 2013

**PhD theses**

Thomas Behrens: The Evolution of B(E2) Values Around the Doubly-Magic Nucleus $^{132}$Sn, TU München 2009

Peter Maierbeck: Untersuchung von Ein-Teilchen-Zuständen in neutronenreichen Kalzium- und Titanisotopen, TU München 2009

Sabine Schwertel: Hochsegmentierte CVD Diamant Detektoren und hochauflösende Impulsmessungen in Knockout Reaktionen TU München 2009

Vinzenz Bildstein: Exploring the Island of Inversion with the d($^{30}$Mg,p)$^{31}$Mg Reaction , TU München 2010

Christoph B. Hinke: Spectroscopy of the doubly magic nucleus $^{100}$Sn and its decay, TU München, 2010

Kathrin Wimmer: Discovery of the shape coexisting 0+ state in $^{32}$Mg , TU München 2010

Thomas Brunner: In-Trap Decay Spectroscopy for ββ Decays, TU München, 2011

Katrin Straub: Zerfallseigenschaften von Nukliden in der Umgebung von $^{100}$Sn, TU München, 2011

Olga Lepyoshkina: Coulomb Excitation of $^{32}$Ar and $^{34}$Ar Proton Rich Nuclei, TU München, 2013

Konrad Steiger: Decay spectroscopy of neutron-rich nuclei around $^{37}$Al, TU München, 2013

## REFERENCES


[1] R. Hertenberger et al., Eur. Phys. J. A42 (2009) 339

[2] H.-F. Wirth, PhD thesis, TU München, 2001

[3] N. Warr et al., Eur. Phys. J. A49 (2013)40



* thomas.faestermann@mytum.de