Future Nuclear Structure Physics at PN1
("Lohengrin")

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Many areas of physics and chemistry can be studied
with the "Lohengrin" mass separator. Only one area for
possible future physics is discussed, the nuclear struc-
ture of exotic neutron-rich nuclei.

The advent, last decade, of large 4π-arrays of high-
resolution germanium detectors [1] for γ-ray spectroscopy
revolutionised nuclear physics, allowing the observation
of such exotic effects as superdeformation [2]. The next
generation of these arrays is at present under develop-
ment, and these will facilitate the tracking of γ-rays
through a detector. The future use of such an array at
"Lohengrin" would be the first use of an efficient γ-ray
detector array for the analysis of fission fragments from
a reactor. The investigation of exotic neutron-rich nuclei
would move the neutron drip line (the point beyond which
nuclei cannot exist) would become possible.

One of the major goals of nuclear physics is to test how
well nuclear models describe exotic nuclei. Present
models have only been tested with nuclei close to sta-
Bility. Such exotic effects as nuclear skins, nuclear
phase transitions and the disappearance of shell gaps
have already been hinted at. Magnetic moment mea-
surements would also be possible, which are known to
be sensitive probes of the nuclear wavefunction.

This region is also important to astrophysics as these
nuclei lie along the path of the r-process. The r-process
is thought to be the method of synthesis for about half
of the matter heavier than iron found in nature [3].

Measurements of nuclear properties in this region are
therefore of great importance to astrophysics. The
recently installed beam switching facility on "Lohengrin"
will allow measurements of the β-decay half-lives of
these nuclei to be performed. It will soon be possible
to measure delayed neutron decays from these nuclei,
with the neutron detector currently being assembled.

1. Introduction

Nuclei are one of the fundamental building blocks of the uni-
verse, sitting in between atoms and hadrons. Nuclei make up
more than 99% of the known mass in the universe; therefore
it is of fundamental importance to understand their properties
and structure. Stable nuclei constitute less than 10% of all the
nuclei thought to be bound systems. Nuclear physics ex-
periments have so far only been able to investigate nuclei close to

2. The "Lohengrin" Mass Separator

Very neutron-rich nuclei are created at the PN1 ("Lohengrin")
pile position by the neutron-induced fission of uranium, or
transuranium, isotopes. These nuclei are then separated, accord-
ing to their mass and charge, by the electromagnetic fields of
"Lohengrin" [4]. Nuclei with excited-state isomers of a micro-
second, or longer, then decay by γ-ray emission. Excited states
on can also be created in nuclei, at the exit slit of "Lohengrin", by β+-
decay. It is from observations of the γ-rays emitted by these excited
states that much information can be obtained about the structure of
nuclei.

3. Structure of Neutron-Rich Nuclei

Knowledge of the energies of excited states in nuclei is essential
to determine the structure of a nucleus. High-resolution γ-ray
spectroscopy is one available method to determine the energies of
excited states. The measurement of angular correlations between γ-rays from
the same nucleus is a well-established method for determining
the spins of excited states in nuclei. The characteristic angular
anisotropy of the position of detection of many pairs of γ-rays from nuclei
being related to the initial and final spins of the levels. To per-
form these measurements good detector angular resolution
is needed, which requires placing conventional γ-ray detectors
somewhere among the γ-ray detectors to the far away from the source. The angular
eaxial angle covered by each detector, hence reducing the detector-efficiency.

Thus for good detection efficiency, many detectors are required, greatly increasing the cost. For nuclei pop-
ulated weakly very large arrays, such as EUROBALL (~100% effi-
cient), with hundreds of detectors must be used. The best reso-
nation of γ-ray detectors, such as MINIBALL [5], facilitate the
tracking of γ-ray interactions through the germanium crystal by
giving excellent position resolution, whilst retaining the abil-
ity to be placed close to the γ-ray source. This new technique
will allow angular correlations to be measured for very weakly
populated nuclei with as few as eight detectors (MINIBALL - ~13% efficient).

Magnetic moments of nuclei are known to be sensitive probes of
the nuclear wavefunction. For instance the predicted γ-decay gen-
nerated by single-particle motion (Schmidt moment), of the 5
state of 208Sn is ~0.35 μN, whereas it is expected to be ~0.26 μN when
using the interacting boson model is used [6]. For excited state
levels of 4 ps, or less, the best method for measuring magnetic
moments of nuclei is to observe perturbed γ-ray angular corre-
lations. This method has been used successfully for excited-state
states as short as 1 ps, with a variety of different techniques
available to the experimenter. The high angular resolution required
using the γ-ray tracking facilities of MINIBALL would make it ideal for these experiments.

4. The Astrophysical r process

The astrophysical r-process is thought to be the method by which
all of the matter, heavier than iron, in nature was created.

Novel neutrons are synthesised by neutron capture during a super-
nova explosion. Predictions about the path of the r-process, and
the predicted yields of the nuclei vary widely from those observed in
nature. Nuclear structure information, for r-process nuclei is
essential for the development of this important model. For instance quenching of shell gaps is required by r-process calcu-
lations to give the observed isotopic abundance found in nature.

Accurate β-decay lifetimes are essential to calculate the speed
at which the r-process proceeds. When neutron binding energies
drop below about 2 MeV neutron capture is inhibited and the nuclei
must first undergo β-decay, before more neutrons can be added
to the nucleus. The nuclei on the r-process path passing for β decay are
called waiting point nuclei. The recently installed beam chop-
ner at "Lohengrin" will allow a pulsed beam of fission fragments
to be produced. Timing measurements between the start of the
beam pulse, and the observation of β particles is one possible
method available to determine the β-decay half-lives of very
neutron-rich r-process nuclei.

5. Delayed Neutrons

Delayed neutrons emitted from β decay have implications for reac-
tor control dynamics. The neutron detector currently being as-
sembled at "Lohengrin" will allow the study of these neutrons. The
study of delayed neutrons, in coincidence with γ-ray emission, will
also be of use to nuclear structure studies as delayed neutrons
populate different excited states to those populated by β decay.
Very little study has been made of delayed neutrons, and the excited
states in their daughter nuclei.

REFERENCES

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