# New Experimental Campaign on the $^{20}$Ne $g(4_1^+)$ Factor ◊

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The self-conjugate T=0 nucleus $^{20}$Ne plays an eminent role for nuclear structure studies. The simple configuration space allows detailed shell model calculations to describe its specific nuclear properties which are generally believed to be well understood. Since this nucleus exhibits a clear rotational band structure and shows backbending at relatively low angular momentum ($I = 6^+$) a study of these effects in $^{20}$Ne was highly desirable for their microscopic understanding in heavier nuclei. The $g$ factors of the nuclear states can be expressed by the isoscalar values as given by

$$g_0(I) = \frac{\mu_0(I)}{I} = \frac{1}{2} + \frac{\mu_p + \mu_n - 1/2}{I}\langle S_3\rangle$$

where $\langle S_3\rangle$ represents the spin density. Taking into account the small admixtures from the lowest T=1 and T=2 states to the dominating T=0 component the predicted $g$ factor values of the first two excited states in $^{20}$Ne are $g(2_1^+)$=0.510 and $g(4_1^+)$=0.511 [1].

Precession measurements in the $4_1^+$ state require the large transient magnetic fields in polarized ferromagnets since the lifetime of the $4_1^+$ state is extremely short (92 fs). The already known $g(2_1^+) = 0.54(4)$ was used for the calibration of the field strength. The final experimental result of $g(4_1^+) = 0.13(15)$ [2] derived by several earlier measurements with the transient field technique, performed by our own group and the Rutgers group [3], turned out to be significantly smaller than the prediction and gave reason to many discussions. The rotational alignment of a neutron pair was suggested as explanation for this surprising result but stands in striking contradiction to current nuclear structure theories. The increasing improvement of the TF technique and its successes within the last two decades were the reason for a new experimental campaign which we started in collaboration with the Rutgers group to bring light into the mystery of the $^{20}$Ne $g(4_1^+)$-factor.

The new measurements were performed at the Cologne tandem accelerator. As in the previous experiments, a carbon beam was used to populate the neon states in the resonant fusion reaction $^{12}$C($^{12}$C,$\alpha\gamma$)$^{20}$Ne at bombarding energies of 32.6 MeV (corresponding to the $4_1^+$ resonance) and 34.5 MeV for both, the $2_1^+$ and the $4_1^+$ states. The neon nuclei were produced in carbon of a multilayered target, consisting of a 150 $\mu g/cm^2$ natural carbon layer, followed by 3 $mg/cm^2$ gadolinium evaporated on a 1 $mg/cm^2$ thick tantalum foil which was backed by 2.6 $mg/cm^2$ copper. In the polarized gadolinium layer the large transient magnetic fields cause the precession of the two nuclear states before the neon nuclei are stopped.

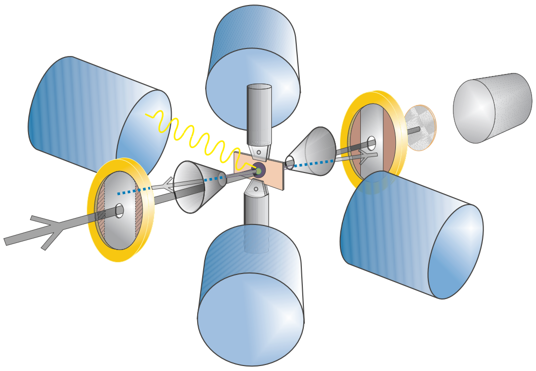

Fig. 1: *Experimental setup showing NaI(Tl) scintillators at angles symmetric to the beam axis, a Ge detector at 0° and two annular Si detectors*

The deexcitation $\gamma$-rays were measured in four large volume NaI(Tl) scintillators in coincidence with the $\alpha$ particles detected in Si detectors (Fig.1). A significant improvement compared to former experiments with only one particle detector at 180° was the use of an additional Si detector placed at 0°.This arrangement enabled the simultaneous measurement of TF precessions at two different ion velocities, associated with forward and backward emitted $\alpha$ particles; it also implied considerably larger particle yields in the forward detector. Spin alignment was enhanced by two copper masks on both particle detectors. In addition, a Ge detector was placed at 0° to the beam axis to measure the lifetimes via the *Doppler Shift Attenuation Method* (DSAM). For both particle detectors and energies a set of three independent data was obtained: the precessions of the directly populated $2_1^+$ and $4_1^+$ states and the precession of the $2_1^+$ state populated via the $4_1^+$ state. Apart from the non-zero precessions of the $4_1^+$ state, in all independent data sets, the strongest indication for equal $g$ factors of the $2_1^+$ and $4_1^+$ states in $^{20}$Ne is the agreement of the precessions in the directly and indirectly populated $2_1^+$ state. Using the linear parametrization to account for the different ion velocities, all experimental data were treated in a $\chi^2$ minimalization procedure. The result,

$$g(4_1^+) = 0.43(9),$$

is in excellent agreement with the prediction. In addition the lifetimes of the $2_1^+$ and $4_1^+$ states could be confirmed, while the value of the first $4_1^-$ state was significantly improved compared to the literature value.

## References

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