Nuclear moments of neon isotopes in the range from ^{17}Ne at the proton drip line to neutron-rich ^{25}Ne

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Nuclear moments of odd-*A* neon isotopes in the range $17 \leqslant A \leqslant 25$ have been determined from optical hyperfine structures measured by collinear fast-beam laser spectroscopy. The magnetic dipole moments of ^{17}Ne, ^{23}Ne, and ^{25}Ne, as well as the electric quadrupole moment of ^{23}Ne, are either reported for the first time or improved considerably. The measurements also decide for a $1/2^+$ ground state of ^{25}Ne. The behavior of the magnetic moments of the proton drip-line nucleus ^{17}Ne and its mirror partner ^{17}N suggests isospin symmetry. Thus, no clear indication of an anomalous nuclear structure is found for ^{17}Ne. The magnetic moments of the investigated nuclei are discussed in a shell-model approach.

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I. INTRODUCTION

In the region of light nuclei even small changes in the number of nucleons can involve significant changes of the nuclear properties. Particularly when the proton or neutron drip line is approached, the nuclear structure may be affected by the low binding energy of individual nucleons. Measurements of the nuclear ground-state observables, such as electromagnetic moments and mean-square charge radii, can serve as sensitive test of the pertinent theoretical models.

Deformation properties have been observed in the excitation spectra of the stable neon isotopes ^{20}Ne, ^{21}Ne, and ^{22}Ne [1]. Conversely, ^{18}Ne at the $N = 8$ shell closure as well as the isotopes around ^{26}Ne with a filled $1d_{5/2}$ subshell are assumed to be spherical [2,3]. In the "island of inversion" [4,5] close to $N = 20$ deformation effects are produced by the influence of *pf*-shell intruder states.

The proton drip-line nucleus ^{17}Ne is of particular interest. With two valence protons bound by only 0.94 MeV and a relatively large matter radius [6], ^{17}Ne is seriously considered as a proton halo candidate [7–9]. Although the halo structure is well established for light neutron-rich nuclei, the occurrence of proton halos in nuclei at the proton drip line is still under discussion. Especially the evidence for ^{17}Ne is not conclusive and further experimental and theoretical studies are needed to clarify the case.

Using fast-beam collinear laser spectroscopy we have conducted an extensive study of nuclear ground-state properties in the range of neon isotopes from ^{17}Ne at the proton drip line, across the valley of stability, to the neutron-rich nuclei ^{26}Ne and ^{28}Ne. The measurement of optical isotope shifts yields the nuclear charge radius of the proton halo candidate ^{17}Ne in comparison with the neighboring neon isotopes. This will be treated in a separate article. The present article is devoted to the investigation of hyperfine structure of the odd-*A* neon isotopes, from which in particular the nuclear moments of ^{17}Ne, ^{23}Ne, and ^{25}Ne are deduced. In this context we examine the implications of a halo structure for the magnetic moment of ^{17}Ne ($Z = 10$, $N = 7$) reflecting the ground-state wave function. This should be produced by a single neutron hole in the $1p_{1/2}$ subshell. However, it turns out that the proton pair in the *sd* shell also plays an important role.

Apart from clarifying the properties of ^{17}Ne, the measured nuclear moments may be used in particular to examine the validity of current *sd*-shell models outside the valley of stability. For many nuclei with $A = 17$–39, shell-model calculations (see, e.g., Refs. [10,11]) have been remarkably successful in predicting the nuclear moments as well as a large variety of other nuclear properties. These calculations [11] use the full *sd* shell as an active model space together with the W or universal *sd* (USD) interaction [12]. Thus, in addition to testing the scope of the proton-halo picture, the present measurements on odd-*A* neon isotopes give insight into the structure underlying the nuclear magnetic dipole and electric quadrupole moments in the region between the neutron shell closures $N = 8$ and $N = 20$.

II. EXPERIMENT

The experiments described in the present article were performed on the 60-keV ion beams of neon isotopes from the ISOLDE on-line isotope separator facility of CERN. The hyperfine structures (hfs) in the transition $2p^5 3s[3/2]_2^\circ \rightarrow 2p^5 3p[3/2]_2$ ($\nu = 16274.02$ cm^{-1}) of the atomic spectrum of neon were measured by the use of collinear fast-beam laser spectroscopy (see, e.g., Ref. [13]). The lower $3s[3/2]_2^\circ$ state is metastable and is efficiently populated by neutralizing Ne$^+$

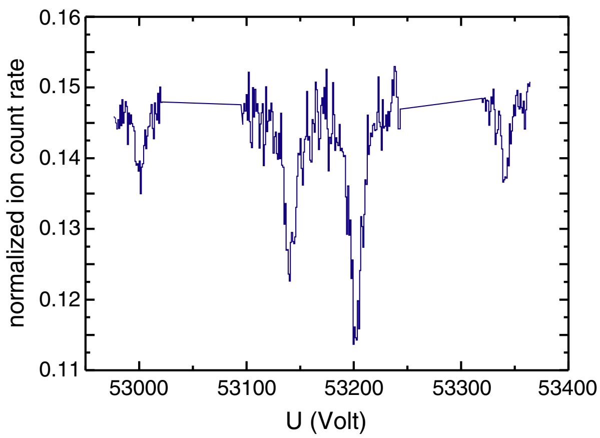

FIG. 1. (Color online) Hyperfine structure of ^{17}Ne detected by β-activity counting. The spectrum was recorded during 1 hr with a yield of ^{17}Ne from the separator of 3500 ions per proton pulse.

ions in a near-resonant charge-exchange reaction with neutral sodium atoms. This reaction takes place when the beam passes through the "charge-exchange cell," a heated, temperature-controlled vessel containing liquid sodium. Atoms in the metastable state are resonantly excited by the laser light to the $3p[3/2]_2$ state, which either decays back to the metastable state or cascades with high probability to the $2p^6\ {}^1S_0$ ground state. The experimental procedure and detection technique was similar to the one used in earlier measurements on argon isotopes (for details see Ref. [14]). The detection of optical resonance is based on collisional ionization [15] for which different cross sections discriminate between the population of the metastable state and the ground state. The ions created on the passage of the beam through a Cl_2 gas target are deflected either onto the cathode of a secondary electron multiplier for ion counting or onto a tape system for β-radioactivity counting. In the same way neutral atoms are counted in the forward direction.

This nonoptical detection method was decisive for the very high sensitivity and isotope selectivity of the experiment. Especially for short-lived isotopes the detection of β-decay electrons or positrons ensures the rejection of isobaric background. Fluctuations in the count rates because of primary beam intensity changes are removed by normalizing the ion counts to the total of counts from ions and neutral atoms. Thus it was possible to perform hfs measurements on isotopes with half-lives smaller than 100 ms with yields from ISOLDE down to 10^3 ions per proton pulse (every 2.4 s). An example is shown in Fig. 1 for ^{17}Ne. According to the nuclear spin $I = 1/2$ one obtains a four-component hyperfine structure that contains the magnetic splitting of the lower and upper state of the optical transition.

For such a measurement the laser frequency ν_L is kept constant. Tuning of the optical frequency in the rest frame of the atoms is performed by varying the ion-beam energy by a computer-controlled electrical potential applied to the charge-exchange cell. Thus, the position of an atomic resonance is determined by the total kinetic energy of the atoms (about 60 ± 10 keV) at resonance with the optical transition (see Fig. 1). The shifted transition frequency is connected to the beam energy via the following Doppler shift formula:

$$\nu(\beta) = \nu_L = \nu_0 \frac{1+\beta}{\sqrt{1-\beta^2}}, \tag{1}$$

where

$$\beta = \frac{v}{c} = \frac{\sqrt{eU(2mc^2+eU)}}{mc^2+eU} \approx \sqrt{\frac{2eU}{mc^2}}. \tag{2}$$

Here ν_0 is the resonance frequency of the atomic transition in the rest frame of atoms, and the + sign in the numerator of Eq. (1) refers to the laser beam and the ion beam propagating in the same direction. The relative beam velocity β is related to the beam energy eU and isotope mass m by Eq. (2), which is accurate enough in the nonrelativistic approximation.

Generally the observed hyperfine structures were well resolved. The spectra were fitted by a sum of resonance curves with positions correlated by the hyperfine structure formula [see Eq. (3)]. The common line shape was modeled by the convolution of a Lorentzian-shaped resonance and an exponential function. As shown and discussed earlier [16], this is a realistic model for the asymmetric line shape observed when an ion beam is neutralized in a collisional charge-exchange process. The minimization procedure was carried out using the function minimization package MINUIT [17].

III. RESULTS

The magnetic dipole interaction constant A and the electric quadrupole interaction constant B for a particular isotope and atomic state is given by the two-parameter, first-order formula (see, e.g., Ref. [18]) for the hfs energies of the levels with total angular momentum F ($|I-J| \leqslant F \leqslant I+J$) as follows:

$$W(F) = \frac{1}{2}AC + B\,\frac{(3/4)C(C+1) - I(I+1)J(J+1)}{2I(2I-1)J(2J-1)}, \tag{3}$$

$$C = F(F+1) - I(I+1) - J(J+1). \tag{4}$$

The measured nuclear spins I and the A and B factors of both levels of the investigated transition, $3s[3/2]_2^\circ$ and $3p[3/2]_2$, are compiled in Tables I and II. The results for the $3s[3/2]_2^\circ$ state of ^{21}Ne agree well with those of an atomic beam experiment [19] giving $A = -267.68(3)$ MHz and $B = -111.55(10)$ MHz. All other A and B factors are reported here for the first time. In the case of ^{25}Ne the observed four-component hfs pattern decides for one of the existing spin assumptions [20], namely $I = 1/2$.

Values of the magnetic moments were obtained according to the relation $\mu^x/\mu^{21} = (A^x I^x)/(A^{21} I^{21})$. This equation holds if hfs anomaly effects can be neglected. For light elements one expects an anomaly of the order of 10^{-4} [21], which is below the error limit of the experimental magnetic moments (see Table I). The magnetic moment of the reference isotope ^{21}Ne, $\mu^{21} = 0.661797(5)\,\mu_N$, including the current diamagnetic shielding correction [22], is known with high precision from an atomic beam magnetic resonance measurement [23]. The evaluation of μ^x was based on the A factors of the $3s[3/2]_2^\circ$

TABLE I. A factors and magnetic dipole moments of the odd-A neon isotopes. The error of the reference moment is negligible compared to the errors of the magnetic moments given by the statistical errors of the A factors. Results of earlier measurements of the magnetic moments of ^{19}Ne [24], ^{21}Ne [23], and ^{23}Ne [25], a recent value for ^{17}Ne [26], and earlier *sd*-shell model predictions are given for comparison.

A	I^π	$A(3s[3/2]_2^\circ)$ (MHz)	$A(3p[3/2]_2)$ (MHz)	μ^{exp} (μ_N) present work	μ^{exp} (μ_N) other works	μ^{cal} (μ_N) [10]
17	$1/2^-$	+955.3(1.7)	+663.3(1.5)	+0.7873(14)	0.74(3)	—
19	$1/2^+$	−2286.9(1.0)	−1588.0(9)	−1.8846(8)	−1.88542(8)	−1.96
21	$3/2^+$	−267.62(15)	−185.83(21)	ref.	−0.661797(5)	−0.66
23	$5/2^+$	−261.4(1.0)	−181.7(7)	−1.077(4)	−1.08(1)	−1.11
25	$1/2^+$	−1220.9(6)	−847.2(5)	−1.0062(5)	—	—

state, because for the reference isotope this A factor [19] is known more accurately than from the present experiment. The magnetic moments derived in this manner are compiled in Table I.

Only two of the investigated odd-A neon isotopes, ^{21}Ne and ^{23}Ne, have spins $I > 1/2$ giving nonzero spectroscopic quadrupole moments. The quadrupole moment of ^{21}Ne (Table II), including a Sternheimer shielding correction, had been obtained from a parametric analysis of optical hfs splitting data [27]. In the present work the value and sign of the quadrupole moment of ^{23}Ne was deduced from the relation $Q_s{}^x/Q_s{}^{21} = B^x/B^{21}$, which holds for any pair of isotopes and given atomic state. In analogy to the evaluation of the magnetic moments, the B factors of the $3s[3/2]_2^\circ$ level were used.

IV. DISCUSSION

A. Nuclear moments of *sd*-shell nuclei

The electromagnetic moments of *sd*-shell nuclei have been predicted rather reliably on the basis of shell-model calculations [11]. Calculations using complete *sd*-shell-space wave functions and empirical M1 single-particle matrix elements were already reported [10] for the $1/2^+, 3/2^+$, and $5/2^+$ ground states of ^{19}Ne, ^{21}Ne, and ^{23}Ne (see Table I). There, two different empirical Hamiltonians were used for the regions $17 \leqslant A \leqslant 28$ and $28 \leqslant A \leqslant 39$. More recent calculations for the *sd* shell are based on the "model-independent" USD (universal *sd*) approach and the corresponding effective interaction (W interaction) [11,30], which treats the two-body matrix elements and single-particle energies as parameters in a least-squares fit to experimental binding and excitation energies. For a theoretical understanding of the magnetic moments we have performed new calculations for the isotopes ^{19}Ne, ^{21}Ne, ^{23}Ne, and ^{25}Ne studied in the present work.

These *sd*-shell model predictions for the neon magnetic moments with the USD [11] and CW [10] Hamiltonians are given in Table III. For each of these we give the results obtained with the free-nucleon M1 operator and with the Brown-Wildenthal effective M1 operator from Ref. [11].

The results obtained with the USD and CW interactions are similar, the effective-operator results being in best agreement with experiment. The wave functions for the neon isotopes with neutrons filling gradually the *sd* shell display a rapid change in structure from collective to single particle. ^{19}Ne has a collective wave function, and the magnetic moment comes from neutron spin terms dominated by a coherent mixture of $2s_{1/2}$, $1d_{5/2}$, and $1d_{3/2}$ contributions with a smaller isovector orbital term. ^{21}Ne also has a collective wave function, but in this case the magnetic moment is dominated by the $1d_{5/2}$ contribution. The ^{23}Ne wave function is dominated by the structure of one-neutron hole in the $1d_{5/2}$ orbit, but there is a cancellation of about 20% from the core-polarization type $1d_{5/2}{-}1d_{3/2}$ neutron excitation.

The deviation from experiment is largest for ^{25}Ne. In the full *sd* shell, the ^{25}Ne $1/2^+$ wave function is dominated by a neutron in the $2s_{1/2}$ orbit (with a free-nucleon magnetic moment of −1.913), but in this case $1d_{5/2}{-}1d_{3/2}$ neutron core-polarization type excitation cancels about half of the dominant $2s_{1/2}$ contribution. The larger experimental value compared to theory indicates that the cancellation is not quite as large as that calculated. This indicates that the interaction leading to the core polarization has become weaker in this neutron-rich nucleus. Another consideration for neutron-rich *sd*-shell nuclei is the mixing with the *pf* shell which is important for ^{28}Ne [5] and may already have some influence in ^{25}Ne.

For the quadrupole moments the comparison between theory and experiment is less quantitative than for the magnetic moments. There are two reasons for this: (*i*) the E2 matrix elements are more complicated than those for the M1 operator,

TABLE II. B factors and deduced spectroscopic quadrupole moments Q_s for isotopes with spin $I > 1/2$. The error in square brackets accounts for the uncertainty of the reference Q_s. Theoretical values from several *sd*-shell calculations are given for comparison.

A	$B(3s[3/2]_2^\circ)$ (MHz)	$B(3p[3/2]_2)$ (MHz)	$Q_s{}^{\text{exp}}$ (b)	Ref. for Q_s^{exp}	$Q_s{}^{\text{cal}}$ (b) [28]	[29]
21	−111.7(5)	−68.4(1.1)	0.1029(75)	[27]	0.103	0.1029
23	−156(6)	−97(4)	0.145(6)[12]	this work	0.144	—

TABLE III. Magnetic moments of *sd*-shell neon isotopes in comparison with the results of different shell-model calculations. All magnetic moments are given in units of the nuclear magneton μ_N.

		μ (μ_N) exp	Free-nucleon M1 operator		Effective M1 operator [11]	
			USD [11]	CW [10]	USD [11]	CW [10]
^{19}Ne	$1/2^+$	−1.885	−2.038	−2.057	−1.880	−1.856
^{21}Ne	$3/2^+$	−0.662	−0.774	−0.824	−0.741	−0.688
^{23}Ne	$5/2^+$	−1.077	−1.071	−1.128	−1.177	−1.136
^{25}Ne	$1/2^+$	−1.006	−0.844	−0.852	−0.873	−0.867

because they require explicitly the radial wave function [11], and (*ii*) the experimental values of the quadrupole moments have larger errors, and often the absolute calibration, depending on the atomic properties, is subject to uncertainties of about 10%. Experimental values of quadrupole moments of *sd*-shell nuclei ($A = 17$–39) have been compared in several theoretical investigations (e.g., Refs. [11,29]), with the predictions from wave functions calculated in the full *sd*-shell model space. The calculations were made using "realistic" effective interactions of different types. The calculated quadrupole moments Q_s depend on the assumptions about the radial dependence of the single-particle wave functions and about the effective charge of the model particles (e.g., standard effective charges of 1.35 e for the proton and 0.35 e for the neutron) in a correlated fashion. Wave functions in a harmonic oscillator ($h\omega = 45A^{-3/2} - 25A^{-1/3}$) or in a Woods-Saxon potential [29] lead to slightly different values. Results of such calculations for the $I > 1/2$ isotopes ^{21}Ne and ^{23}Ne are presented in Table II. As shown in a more general comparison [29] there is not always perfect agreement, but no systematic difference between experimental and theoretical values.

B. Magnetic moment of ^{17}Ne

Theoretical studies dealing with the properties of the proton drip-line nucleus ^{17}Ne have been concentrated on the possible halo structure. Several models have been applied to investigate the dominant *sd*-shell orbits of the proton pair outside the ^{15}O core and their implications for a spatially extended wave function. First we discuss qualitatively how halo properties should be reflected by the magnetic moment.

In a single-particle model, the ground state of ^{17}Ne is formed by a hole in the $1p_{1/2}$ neutron orbit for which the Schmidt moment is $+0.638\ \mu_N$. The proton pair in the *sd* shell is coupled to $J = 0$ and thus gives no contribution. The experimental magnetic moment of ^{17}Ne, given in Table I, is about 20% larger than the Schmidt value, falling outside the region between the Schmidt lines for odd-neutron nuclei.

For ^{17}N, the mirror partner of ^{17}Ne, the situation is analogous [31]. The magnetic moment, $\mu(^{17}\mathrm{N}) = -0.352(3)\ \mu_N$, has to be compared to a Schmidt value of $-0.264\ \mu_N$. Most remarkably, as in the case of ^{17}Ne, the deviation is outwardly directed, whereas nearly all experimental magnetic moments fall into the region between the Schmidt lines. This finding motivates the investigation of isospin symmetry for the mirror pair ^{17}N–^{17}Ne.

Sugimoto [32] analyzed the magnetic moments of mirror nuclei in the framework of a one-body operator and charge symmetry and gave a systematics of the isoscalar moments. The sum of the magnetic moments of two mirror partners (i.e., twice the isoscalar part of the magnetic moment) is given by the following:

$$\mu(T_z = +T) + \mu(T_z = -T) = I + \left(\mu_p + \mu_n - \frac{1}{2}\right)\left\langle \sum_i \sigma_z^{(i)} \right\rangle_I. \quad (5)$$

Here I is the total angular moment of the nucleus, μ_n and μ_p are the magnetic moments of the free nucleons (all moments in units of the nuclear magneton μ_N). For $T = 1/2$ and $T = 3/2$ mirror nuclei the quantity $\langle \sum_i \sigma_z^{(i)} \rangle_I$ can be directly compared to the single-particle value corresponding to the sum of the Schmidt moments.

In Fig. 2 this comparison is shown for nuclei in the $1s$, $1p$, and $2s1d$ shells. Data are taken from compilations of nuclear moments [22] and from more recent original publications [31,33,34], including the present work. For the majority of mirror pairs the expectation values $\langle \sum_i \sigma_z^{(i)} \rangle_I$ follow systematic trends throughout the shells and lie within limits given by the corresponding isoscalar single-particle Schmidt moments. As suggested in Refs. [32] and [34], deviations from

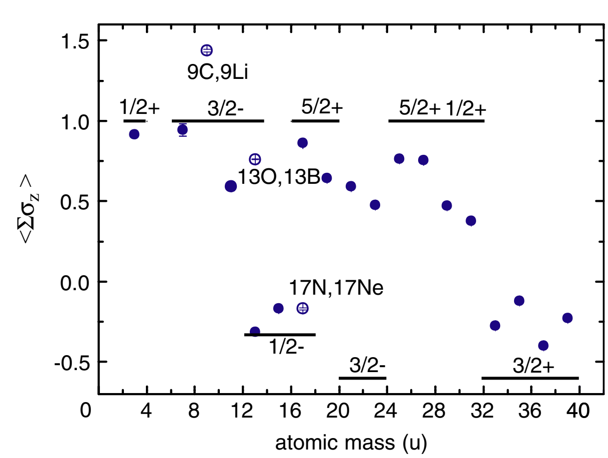

FIG. 2. (Color online) Systematics of isoscalar moments, including experimental magnetic moments of $T = 1/2$ and $T = 3/2$ mirror nuclei. The filled circles represent data of nuclei with isospin $T = 1/2$, the open circles denote nuclei with $T = 3/2$. Single-particle values are drawn as lines for the corresponding spin and parity, I^π.

TABLE IV. Shell-model predictions for the magnetic moments of the mirror pairs ^{17}Ne–^{17}N and ^{15}O–^{15}N and comparison to the experimental values.

	I^{π}	μ (μ_N) exp	WBP [36]	
			Free-nucleon M1 operator	Effective M1 operator
^{17}Ne	$1/2^-$	0.787	0.712	0.795
^{17}N	$1/2^-$	−0.352	−0.333	−0.350
^{17}Ne-^{17}N	$1/2^-$	1.139	1.045	1.145
^{17}Ne+^{17}N	$1/2^-$	0.435	0.379	0.445
$\langle\sigma\rangle$		−0.171	−0.318	−0.145
^{15}O	$1/2^-$	0.720	0.638	0.722
^{15}N	$1/2^-$	−0.283	−0.264	−0.285
^{15}O-^{15}N	$1/2^-$	1.003	0.902	1.007
^{15}O+^{15}N	$1/2^-$	0.437	0.374	0.437
$\langle\sigma\rangle$		−0.166	−0.332	−0.166

these trends can be taken as a hint of anomalous nuclear structure implying isospin asymmetry. Such a behavior is observed for the $T = 3/2$ mirror pair ^{9}Li–^{9}C (see, Fig. 2), for which a standard shell-model calculation predicts $\langle\sigma\rangle = 1.03$ [35]. According to [34], the anomalous behavior has to be attributed to an unusual ground-state configuration of the proton drip-line nucleus ^{9}C. In contrast to this, the mirror pair ^{17}N–^{17}Ne matches very well the general trend of isoscalar moments. Of course, this is related to the symmetry in the deviations of the individual magnetic moments of ^{17}N and ^{17}Ne from the Schmidt lines.

A proton halo of ^{17}Ne would involve an isospin asymmetry mainly in the nuclear charge distribution, and it should be examined how this could influence the magnetic moments. From the interpretation of the magnetic moment of ^{17}N given by Ueno *et al.* [31], it is clear that the nucleon pair in the *sd* shell is responsible for the unusual deviation of the $p_{1/2}$ moment from the Schmidt value. Very similarly, the magnetic moment of ^{17}Ne can be explained by the admixture of 2^+ excitations of the type $(\pi\ 1d_{5/2})^2$ to the ground-state wave function, which is dominated by $(\pi\ 1d_{5/2})^2$ and $(\pi\ 2s_{1/2})^2$ coupled to 0^+.

The calculations for ^{17}Ne were carried out in a $0\hbar\omega$ cross-shell *p*-*sd* model space with the WBP interaction [36]. For $0\hbar\omega$ the wave functions are restricted to two particles in the $2s1d$ shell and one hole in the $1p$ shell. For comparison we also show the results for the mirror nucleus ^{17}N and for the $A = 15$ mirror pair ^{15}O and ^{15}N, which are just single-hole states in this $0\hbar\omega$ model space. The effective M1 operator is the same as that used for the *sd* shell, but with an isoscalar spin g factor for the $1p$ orbits adjusted to reproduce the $A = 15$ moments. Our goal here is to understand the change between $A = 15$ and $A = 17$.

The theoretical predictions are shown in Table IV. As can be seen, they nicely reproduce the difference between $A = 17$ and $A = 15$, which comes from the coupling of the p hole to the two particles in the *sd* shell. In comparison to the free-nucleon M1 operator, both $A = 15$ and $A = 17$ show an enhancement of about 10% in the isovector moment and about 15% in the isoscalar moment, which translates into a quenching of the isoscalar $\langle\sigma\rangle$ term by a factor of 2.

The effective operator, which is designed to reproduce $A = 15$, also reproduces very well the moment of ^{17}N. However, the predicted moment of ^{17}Ne is somewhat larger than the experimental one. The calculated value of 0.796 for ^{17}Ne can be decomposed into 0.722 from the $1p$-shell neutron hole and 0.073 from the two *sd*-shell protons. The agreement with experiment for ^{17}Ne could be made exact if the contribution from the two *sd*-shell protons was reduced from 0.073 to 0.065. This change might be related to a 13% reduction in the neutron-proton interaction because of some halo nature of the two *sd*-shell protons in ^{17}Ne.

However, this small effect cannot stand as a strong argument for ^{17}Ne being a nucleus with a well-developed two-proton halo. The shell-model wave function reproducing the magnetic moment of ^{17}Ne is dominated by the $(1d_{5/2})^2$ component for the *sd*-shell proton pair. In detail the contributions (probabilities) are 69% of $(1d_{5/2})^2$, 24% of $(2s_{1/2})^2$, and 7% of $(1d_{3/2})^2$, similar to those for the sd-shell neutrons in the mirror nucleus ^{17}N [31]. This is consistent with the conclusion drawn from the consideration of Coulomb energies within the $A = 17$, $T = 3/2$ isospin multiplet [37]. However, it is clearly in conflict with recent data on the two-proton removal reaction cross section and momentum distribution [38], suggesting a large *s*-wave occupancy and thus favoring a halo structure of the two valence protons. Previous indirect information about the momentum distribution of the weakly bound protons seemed to argue against a halo [39].

It is a necessary condition for the existence of a halo that the *sd*-shell protons occupy the $2s_{1/2}$ state rather than the $2d_{5/2}$ state. Such a dominance of the *s*-wave component is suggested from calculations using a three-cluster generator-coordinate method [8]. Even then the simultaneous investigation of the proton and neutron density distributions and corresponding radii of ^{17}Ne and ^{17}N indicates no halo properties for ^{17}Ne, in contrast to the conclusion from a calculation in a three-body model [7] where the *s*-wave component is smaller. All these arguments may be seen in connection with the qualitative (necessary but not sufficient) criterion given by [40] for the existence of a proton halo: The condition for the two-proton separation energy, $S_{2p}A^{2/3} < 2$–4 MeV, is not met for ^{17}Ne with $S_{2p}A^{2/3} = 6.3$ MeV.

Proton halo properties should be clearly pronounced in the behavior of nuclear charge radii. This aspect and further conclusions about a possible halo structure of ^{17}Ne will be discussed in our forthcoming article on the measurement of isotope shifts and mean-square charge radii in a sequence of neon isotopes.

V. CONCLUSION

Hyperfine structure measurements were performed on five odd-*A* neon isotopes covering a region of particular interest. They range from ^{17}Ne at the proton drip line across the $N = 8$ shell closure and the valley of stability to ^{25}Ne in the upper *sd* shell. Collinear fast-beam laser spectroscopy was performed on neutralized beams of neon isotopes from ISOLDE. The short-lived isotopes became accessible because of the ultrasensitive optical resonance detection, based on state-selective collisional ionization [15] and β-radioactivity counting for discrimination against background [14].

The results comprise directly measured spins and magnetic dipole and electric quadrupole moments. The magnetic moment of ^{19}Ne agrees excellently with the value obtained by nuclear magnetic resonance [24]. The magnetic moment of ^{23}Ne is substantially improved compared to the result [25] of an early atomic-beam magnetic-resonance experiment. The magnetic moments of ^{17}Ne and ^{25}Ne (both $I = 1/2$) and the electric quadrupole moment of ^{23}Ne ($I = 5/2$) have been measured for the first time.

The measured nuclear moments provide a quantitative test of pertinent shell-model calculations. The most important result is the magnetic moment of ^{17}Ne. A comparative shell-model treatment of the $T = 3/2$ mirror pairs for $A = 15$ and $A = 17$ reveals some reduction in the neutron-proton interaction for ^{17}Ne. However, a qualitative discussion gives good arguments for the conclusion that ^{17}Ne, in spite of its small two-proton separation energy, does not exhibit a pronounced proton halo structure.

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