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NUCLEAR CHARGE- AND MAGNETIZATION-DENSITY-DISTRIBUTION PARAMETERS FROM ELASTIC ELECTRON SCATTERING

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A compilation of nuclear charge- and magnetization-density-distribution parameters, found from elastic electron scattering, is presented. The data on charge distributions, obtained on the basis of a phenomenological model, are given in three separate tables: parameters of nuclei, differences therein between isotopes and between other neighbouring nuclei such as isotones. A fourth table is devoted to charge distributions obtained by model-independent analyses. In the final table the available data on magnetization-density distributions are listed. References through April 1974 have been covered.

CONTENTS

INTRODUCTION

Since the early work of Hofstadter and his collaborators, which started about twenty years ago at Stanford University, elastic electron scattering has evolved into a powerful method for studying the electromagnetic structure of nuclei. This was already clearly shown by the 1967 compilation of nuclear charge-distribution parameters prepared by Hofstadter and Collard (Ho67). These authors predicted that the next compilation would be much less simple to make due to the rapid and extensive development in the electron-scattering field. Their prediction proved to be fully justified, as a vast amount of experimental data has been obtained at low and at high values of the momentum transfer. The accuracy in the results has also greatly improved due to both theoretical and instrumental progress.

Full credit to the experimental data could only be given by presenting in this compilation, besides the main table on charge-distribution parameters of nuclei, two additional tables: one on parameter differences between isotopes (Table II) and another on differences between other neighboring nuclei (Table III). Table IV contains results obtained for several nuclei with the recently developed method for analysis of data in a model-independent way. The present authors believe that in the near future results on charge distributions obtained in this way will replace to a large extent the material presented in the first three tables based on phenomenological models. Experimental information on the magnetization-density distribution of nuclei is presented in Table V. Evidently large progress has been made in this field also. With the aid of improved experimental techniques, especially with 180°-scattering apparatus, information can be obtained even for medium-heavy nuclei.

For the present compilation the policy was adopted to tabulate in general only data published since the 1967 compilation because of the large number of new and, in most cases, much more accurate results obtained since then. Older data have been included only for those nuclei which have hardly, or not at all, been studied recently. An effort was made, however, to give a comprehensive list of references, including citations of all experimental papers not incorporated in the tables. It was considered outside the scope of this compilation to pass judgment on the tabulated results, even for those nuclei for which several different and sometimes conflicting results exist. According to the authors this attitude is justified because: (a) regrettably few experiments have been performed, analyzed, or presented in a comparable way; (b) it is difficult to compare the merits of experiments performed over different ranges of the momentum transfer q; and (c) the results are in most cases dependent on the particular model used in the analysis. As a consequence, the tabulated material includes, in addition to the charge-distribution parameters themselves: (a) the model used in the analysis, (b) the range of q-values covered in the experiment, and (c) the nucleus relative to which cross sections have been determined.

This compilation was completed in April 1974 and, therefore, ought to cover all data published up to that date. The authors take full responsibility for omissions in the tabulated material or the list of references. In no case has such an omission been intentional.

In connection with the remark made about the next compilation, the present authors would like to urge all experimental physicists in the field of electron scattering to agree on a standard way in which at least the raw cross-section data are presented. This would greatly facilitate the task of subjecting available data to the model-independent-analysis technique.

Charge-Distribution Parameters

Only a few aspects of elastic electron scattering can be mentioned in this introduction. For more extensive information the reader is referred to recent monographs, such as Refs. Ub71 and Ba74.

The analysis of electron-scattering data is restricted by the fact that the form factor can be determined only over a finite range of the momentum transfer. In Born Approximation the charge distribution $\rho(r)$ is the Fourier transform of the form factor $F(q)$ which for a spherically symmetric charge distribution is given by

$$\rho(r) = \frac{1}{2\pi^2}\int_0^\infty F(q)\,\frac{\sin(qr)}{qr}\,q^2 dq.$$

As a consequence, only the amplitudes of Fourier components of $\rho(r)$ with wavelengths between $2\pi/q_{\max}$ and $2\pi/q_{\min}$ can be determined directly. Most of the results presented in this compilation have been obtained on the basis of a phenomenological model. In this way, however, a bias is introduced in the analysis because the charge density at different values of r is coupled through the use of such a model. Therefore, great care should be exerted in drawing conclusions on general properties of the nuclear charge distribution from the tabulated parameter values. For instance, the "wine-bottle" parameter w, which was introduced as a third parameter in the Fermi model (see Explanation of Table I), is generally more representative for the behavior of the tail of the charge distribution than for that of the inner region (Si74). This is illustrated by the fact that analyses of the same data set with the three-parameter Fermi and with the three-parameter Gaussian model often yield w-values with opposite signs (Av74). Also, the data on the oscillatory behavior of $\rho(r)$, which was introduced to obtain a fit to measurements performed at large values of q, are at best significant only for light- and medium-heavy nuclei (Si73). Even the error bars quoted for the rms radius of $\rho(r)$ do not necessarily represent the full range of rms radii consistent with the experimental data. These limitations can be removed only by the use of a model-independent analysis.

One of the major advantages of electron scattering as a nuclear probe is the fact that the interaction is electromagnetic and hence well known. As a result, for a specified charge distribution the elastic electron-scattering cross section can be calculated by phase-shift analysis techniques (for example Be67c, Fi64) to a degree of accuracy, which is at present more than sufficient. Two major theoretical problems remain to be solved in the electron-scattering field: radiative and dispersive corrections. While presently available calculations of radiative corrections are in good agreement with relative experiments, deviations have been observed in absolute experiments. This seems to indicate that additional higher-order diagrams should be incorporated in the calculations. Dispersive (or virtual nuclear excitation) effects have been the subject of many papers. No reliable calculation is available at present, although the general expectation is that the corrections are not more than a few percent. An indication of this is given by the good agreement between the results obtained from muonic x-ray and from elastic electron-scattering data. In the absence of reliable theoretical estimates experimental proof for the existence of dispersive effects, which might appear as an anomalous behavior of the cross section, is nearly impossible.

In the past numerous attempts have been made to calculate charge distributions from a theoretical basis. Only for the lighter nuclei did the results give reasonable agreement with experimental cross-section data although more recent Hartree–Fock calculations (Ne70, Ne71, Fa72a, Fa72b) with a density-dependent nucleon–nucleon interaction have been fairly successful. With the availability of model-independent results it should be possible to determine more specifically the merits or defects of such theoretical calculations. It is well known that the charge distributions resulting from such calculations should be corrected for the finite size of the protons and the center of mass motion before they can be compared with experimental results. However, recent calculations (Be72c) have indicated that also the neutron charge form factor in some cases contributes significantly to the cross section.

Model-Independent Analysis

Constantly improving experimental accuracy naturally set high standards for data analysis. For some time this resulted in the introduction of more and more free parameters, so that results could be quoted on fine details of the charge distribution like small oscillations or a central dip or hump. However, all information was based on the assumption of a phenomenological model for the charge distribution.

In 1969 Lenz (Le69) was the first to use a different approach. He assumed the nucleus to consist of a number of concentric shells, each shell containing a part of the total charge localized as a δ-function. The width of the shells was chosen smaller than the wavelength of the incoming electron, thus ensuring that the cross section be independent of the shell division. By variation of (a) the number of shells, (b) the radii of the shells, and (c) the distribution of the total charge over the shells, a very general set of charge distributions consistent with the experimental data can be generated. The results are then presented in the form of integral quantities of $\rho(r)$, either the partial moment function $T(Q)$, defined by $T(Q) = \int_0^Q R(Q')dQ'$, where Q is the fraction of the nuclear charge contained in a sphere of radius R or the moment function $M(k)$ defined by $M(k) = \left(\int_0^\infty r^k \rho(r) r^2 dr\right)^{1/k}$ (Fr72b). A drawback of this method is that the generated set of charge distributions is too general to allow a useful comparison between theoretical calculations and experimental results.

Luk'yanov *et al.* (Lu69 and Po69) proposed a method of analysis in which $\rho(r)$ is expanded in a set of orthonormal functions generated from the derivatives of the two-parameter Fermi distribution. Friar and Negele (Fr73) used an expansion of $\rho(r)$ in a Fourier sine series. In both methods only a limited number of coefficients could be determined. The inclusion of more coefficients in the analysis yielded solutions for $\rho(r)$ with large oscillations, generated by high Fourier components which cannot be determined directly from data at momentum transfer values less than the maximum q-value. This unavoidable truncation of the series expansion resulted in a underestimate of the error band for the charge distribution.

A usable model-independent analysis will have to incorporate some model dependence to account for the fact that data are available only over a finite q-range. The limitation should be based on physical arguments. Three methods presently available incorporate a limitation on the form factor at q-values larger than q_{max}.

Sick (Si74) assumed the charge distribution to consist of a sum of Gaussians (SOG). Model dependence is enforced through the width Γ of the Gaussians. The value of Γ is chosen equal to the smallest width of the peaks of nuclear radial wavefunctions calculated by the Hartree–Fock method. Only positive values of the amplitudes of the Gaussians are allowed so that no structures narrower than Γ can be created through interference. An advantage of the use of Gaussians is that the value of $\rho(r)$ at different values of r is decoupled to a large degree because of the rapid decrease of the Gaussian tail. The results of the analysis are independent of the number of Gaussians, provided it is sufficiently large to allow a good fit to the data.

Dreher *et al.* (Dr74) used a Fourier–Bessel expansion of $\rho(r)$. For practical reasons $\rho(r)$ is assumed to be zero beyond a certain cutoff radius R. The first $N(\gtrsim Rq_{max}/\pi)$ coefficients of this series expansion are determined directly from the experimental data. The behavior of the form factor $F(q)$ at large q-values is assumed to be limited by a q^{-4} and an exp $(-aq^2)$ decrease resulting from the distribution of the nucleons in the nucleus and from the finite extension of the nucleons, respectively. These assumptions yield an upper limit for the contributions of the higher Fourier components of the series expansion. The results depend to a certain degree on the value of the cutoff radius R. An advantage of this method is that the uncertainties in the charge distribution originating from the experimental errors and from the lack of knowledge about the large-q behavior of the form factor can be determined separately. In this way one can decide whether it is worthwhile to repeat the experiment over the same q-range with an improved accuracy or to extend the experiment to larger momentum-transfer values.

Borysowicz and Hetherington (Bo73a and He74) developed a very general method in which in principle any model space can be used for the high-q behavior of $F(q)$ and for $\rho(r)$, including its behavior for large r-values. Analyses with a cosine series, a sum of Hermite polynomials, or a set of spline functions for $\rho(r)$ all yielded nearly identical charge distributions. The results did, however, depend on the assumptions made for the high-q behavior of $F(q)$: a q^{-4} and an exp (aq) behavior resulted in significantly different error bands.

In summary, three methods have at present been developed for a model-independent analysis, incorporating assumptions on the behavior of the form factor outside the range of q-values for which experimental data are available. It is expected that all three will yield nearly identical charge distributions for the same data set. The main problem which remains to be settled, is to decide on a generally accepted form of the high-q behavior of the form factor.

In Table IV results are presented for several nuclei analyzed with one of the three methods described above. One should keep in mind that not every charge distribution which falls in the tabulated error band is consistent with the experimental data. To allow a comparison with a model-independent evaluation of muonic x-ray data the equivalent radius for a $2p$–$1s$ muonic transition is also quoted for some nuclei. Large disagreements are not expected since in most cases muonic x-ray data have been included in analysis of electron-scattering data.

Magnetic Scattering

The cross section for elastic scattering of electrons generally consists of two components: one longitudinal, caused by the nuclear charge distribution, and the other transverse, caused by the magnetic-moment distribution. In principle, the transverse magnetic scattering can be separated from the longitudinal charge scattering through the difference in angular dependence. For a determination of the form factor of the magnetic dipole moment, however, this procedure is useful only for the lightest nuclei, i.e., ^{1}H, ^{2}H, ^{3}H, and ^{3}He. In all other cases a 180°-scattering facility is needed because of the strong domination of charge scattering. It is true that magnetic scattering has been observed at "normal" scattering angles for q-values close to minima in the charge form factor, but in most cases (^{27}Al, ^{51}V, and ^{209}Bi) the magnetic-dipole form factor at these q-values is small compared to the form factors of the higher-order magnetic multipole moments. For ^{14}N and ^{15}N only the magnetic dipole moment contributes to the transverse cross section; the fact, however, that the q-values where the data points were taken are far above the first minimum in the magnetic form factor makes an interpretation in terms of a magnetic-dipole-moment distribution very difficult.

Therefore, the tabulated data for nuclei with $Z > 2$ have all been obtained with a 180° set-up, since the table contains only magnetic-dipole-moment parameters. The early experiments performed with such a set-up were restricted to light nuclei (Va65, Ra66); due to experimental improvements it is possible nowadays to measure magnetic form factors for nuclei up to $Z = 27$ (Vr73). For the analysis of these moderately high-Z results the Born Approximation, which could be used successfully for the experimental data before 1972, is not sufficiently accurate. Thanks to an improvement (La73a) of the existing DUELS code the analysis of the most recent elastic magnetic-scattering data could be performed in Distorted Wave Born Approximation.

Since the nuclear magnetic moment originates mainly from the valence nucleons, study of magnetic scattering opens the possibility of obtaining information on the spatial distribution and the coupling scheme of the outermost nucleons. The total magnetization density is composed of an intrinsic spin part (s-part) and an orbital convection current part (l-part). In principle it is possible to convert the total magnetization density to an equivalent pure s- or pure l-magnetization density; the fact, however, that such an equivalent distribution may contain positive and negative components causes extremely large uncertainties in the value of the magnetic rms radius obtained. The method can therefore be applied only to nuclei with nearly pure spin magnetization, such as ^{1}H, ^{2}H, ^{3}H, and ^{3}He. For all other cases it is necessary to introduce a nuclear model for the magnetization-density distribution. In general, simple shell-model wavefunctions are used. Then, the form factor for scattering from the nuclear magnetic dipole moment can in first-order Born Approximation be written (Wi63, Fo66):

$$F_{M1,\text{shell}}(q) = \int R_{nl}^2(r) j_0(qr) d\mathbf{r} + R \int R_{nl}^2(r) j_2(qr) d\mathbf{r} \qquad (1)$$

where $R_{nl}(r)$ is the radial part of the wavefunctions, $j_\lambda(qr)$ is the spherical Bessel function of order λ, and R is a constant determined by the coupling scheme of the nucleons. In the analysis of the experimental data the shell-model form factor $F_{M1,\text{shell}}$ has been corrected for the center of mass motion and for the finite size of the nucleon.

In the extreme single-particle model (SPM) the value of R is given by

$$R_{\text{SPM}} = (\pm(g_s/2)A + g_l B)/(\mp(g_s/2) + g_l B) \qquad (2)$$

where
$$A = \frac{1}{2}(2l + 1 \pm 1)/(2l + 1 \mp 2),$$
$$B = \frac{1}{2}(2l + 1 \pm 1),$$
$$l = j \pm \frac{1}{2}.$$

It is a well-known fact that the extreme single-particle model fails to give an adequate description of the nucleus. Therefore, it is not surprising that in many cases the experimental data cannot be fitted by the formula given above. The magnetic-moment distribution depends on the coupling scheme between the outermost nucleons, on core polarization and mesonic exchange effects. In a first approximation these effects can be accounted for by the introduction of "effective" g_l and g_s factors, that is, by the introduction of R-values differing from those of formula (2). In the analysis R was in some cases fixed at a value based on a model calculation, in other cases R was used as a free parameter. For all existing data it was possible to get adequate fits.

The influence of the shape of the shell-model potential has been investigated (Ra66, Do73); for q-values up to 4 fm^{-1} the calculated form factors turned out to be rather insensitive to the shape of the potential. In the analysis of the data from all but the lightest nuclei the harmonic-oscillator model has been used. For most nuclei so far investigated the experimental data could be fitted by a range of combinations of R and the harmonic-oscillator parameter a_0 resulting, in large uncertainties in the magnetic-dipole-moment distribution. In order to diminish these uncertainties it is necessary to perform magnetic-scattering experiments at least up to momentum transfers of 5 fm^{-1}, thus mapping out the complete magnetization density distribution.

POLICIES

Literature Coverage All available experimental papers were covered, including preprints, theses, and internal reports. No theoretical papers have been included.

Tabulated Results In general only those results published since the previous compilation (Ho67) are tabulated.

Models In those cases where the same data have been analyzed with different models, only results obtained with one particular model have been tabulated, following wherever possible the authors' preference. Unless otherwise stated, the results are for the lowest-order multipole moments ($C0$ and $M1$) only.

Comparison Nucleus In the majority of cases the absolute values quoted for the distribution parameters have been obtained relative to those of standard nuclei such as ^{1}H and ^{12}C. In nearly all cases the most recent results obtained for these standard nuclei have been used. To this effect an appreciable amount of the originally published data has been reanalyzed, mostly by the staff of the laboratories where the experiments were originally carried out.

Errors The errors tabulated have been taken from the original papers. Generally, they represent the total error, the sum of the statistical (one standard deviation) and the systematic errors. No effort has been made to combine the various types of error analyses used into a standard representation.

References References are given to the papers from which the tabulated results have been taken. The list of references has been made as complete as possible. A list of additional references to all material not tabulated is given at the foot of each page. Reference keys are in the style Fr68, where 68 refers to the year and Fr to the name of the first author.

Neighboring Nuclei Differences in charge-distribution parameters between neighboring nuclei can be determined by observing the cross-section ratios to a higher accuracy than the parameters themselves. Therefore, the results of such analyses have been listed in two separate tables. Not included there are the results of experiments where neighboring nuclei have been measured simultaneously, but not analyzed in terms of cross-section ratios. Not included in Table I are charge-distribution parameters which have been obtained through cross-section ratios of neighboring nuclei.

EXPLANATION OF TABLES

TABLE I. Charge-Density-Distribution Parameters

TABLE II. Differences in Charge-Density-Distribution Parameters Between Isotopes

TABLE III. Differences in Charge-Density-Distribution Parameters between Neighboring Nuclei (not Isotopes)

Nucleus	The absence of the mass number indicates that the tabulated values are for a natural isotopic admixture.
Model	A normalization of the charge distribution has been used such that $4\pi\int\rho(r)r^2\,dr = Ze$
	If no entry is given in this column, the model used is described in the remark
HO	Harmonic-oscillator model $\rho(r) = \rho_0(1 + \alpha(r/a)^2)\exp(-(r/a)^2)$ $\alpha = \alpha_0 a_0^2/(a^2 + (3/2)\alpha_0(a^2 - a_0^2))$ $a_0^2 = (a^2 - a_p^2)A/(A-1)$ $\alpha_0 = (Z-2)/3;\ a_p^2 = (2/3)\langle r^2\rangle_{\text{proton}}$
MHO	Modified harmonic-oscillator model, with the same expression for $\rho(r)$ as in HO but with α as a free parameter.
MI	Model-independent evaluation, with a series expansion for the form factor $F(q) = 1 - (1/6)q^2\langle r^2\rangle$
MIA	Model-independent analysis, with a sum of δ-functions for $\rho(r)$ (Le69)
2pF	Two-parameter Fermi model $\rho(r) = \rho_0/(1 + \exp((r-c)/z))$
3pF	Three-parameter Fermi model $\rho(r) = \rho_0(1 + wr^2/c^2)/(1 + \exp((r-c)/z))$
3pG	Three-parameter Gaussian model $\rho(r) = \rho_0(1 + wr^2/c^2)/(1 + \exp((r^2 - c^2)/z^2))$
UG	Uniform Gaussian model $\rho(r) = \rho_0\int_0^R \exp(-(r-x)^2/g^2)x^2\,dx$
$\langle r^2\rangle^{1/2}$	Root-mean-square radius of the charge distribution $\langle r^2\rangle = \frac{4\pi}{Ze}\int\rho(r)r^4\,dr$
c or a	In this column the values are given for the parameter c if the 2pF, 3pF or 3pG model has been used and for the parameter a if the HO or MHO model has been used
z or α	In this column the values are given for the parameter z if the 2pF, 3pF or 3pG model has been used and for the parameter α if the HO or MHO model has been used

TABLES I, II, and III (*continued*)

w	The parameter w of the 3pF and 3pG model
q-range	The momentum-transfer range covered by the data used in the analysis
Comparison Nucleus	The nucleus relative to which the cross-section data have been obtained. The reference given indicates which parameter values for the comparison nucleus have been used.
abs.	Absolute measurement, without the use of a comparison nucleus
Ref.	Key to the list of references at the end of the tables
Remarks	The entries indicated by a letter or the symbol † are explained at the bottom of each page, the numerical entries at the end of each table

Note:

$\Delta\langle r^2\rangle$	$\langle r^2\rangle(A_2) - \langle r^2\rangle(A_1): A_2 > A_1$
Δc	$c(A_2) - c(A_1)$

TABLE IV. Charge-Density Distributions Obtained from Model-Independent Analyses

Method	Type of analysis used
SOG	$\rho(r)$ described as a sum of Gaussians, each with a width Γ
Hermite	$\rho(r)$ described as a sum of odd Hermite polynomials
exp. ass.	An $\exp(-cq)$ behavior of the form factor $F(q)$ for $q > q_{\max}$ was assumed
Cosine	$\rho(r)$ described as a cosine series for $r \leqslant R$
Fourier–Bessel	$\rho(r)$ described as a sum of zero-order spherical Bessel functions for $r \leqslant R$ The charge distribution is assumed to be zero beyond R
Data	The reference from which the cross-section data used in the analysis have been taken
$\langle r^2\rangle^{1/2}$	The rms radius of the charge distribution resulting from the analysis
R_k	The equivalent radius defined by $3R_k^{-3}\int_0^{R_k} \exp(-\alpha r) r^{k+2}\, dr = 4\pi\int_0^{\infty} \rho(r) \exp(-\alpha r) r^{k+2}\, dr$ A value for k corresponding to a $2p$–$1s$ muonic transition is used. The values for α and k were taken from the compilation of muonic atom data in this issue of Atomic Data and Nuclear Data Tables.
$\rho(r)$	The charge-density distribution normalized so that $4\pi\int\rho(r)r^2\, dr = Ze$

TABLE V. Magnetization-Density-Distribution Parameters

μ	Static magnetic dipole moment of the nucleus in nuclear magnetons (data taken from Ref. Fu69)
$\langle r^2 \rangle_M^{1/2}$	Root-mean-square radius of the magnetization-density distribution. In the shell model with a harmonic-oscillator potential this quantity is related to the harmonic-oscillator parameter by $\langle r^2 \rangle_M^{1/2} = (2n + l - \tfrac{1}{2})^{1/2} a_0$.
a_0	Harmonic-oscillator parameter. Entries are given only when the HO model has been used in the analysis
R	The data are fitted with a dipole form factor that is given by $F_{M1}(q) = \int R_{nl}^2(r) j_0(qr)\, d\mathbf{r} + R \int R_{nl}^2(r) j_2(qr)\, d\mathbf{r}$ where R_{nl} is the radial part of the wavefunction of the outermost nucleon, $j_\lambda(qr)$ the spherical Bessel function of order λ and R a constant, determined by the coupling scheme and the effective gyromagnetic ratios of the outermost nucleon
R_{SPM}	The value of R as expected in the extreme single-particle model. For odd–odd nuclei the predicted value in extreme j–j coupling is given
q-range	The momentum-transfer range covered by the data used in the analysis
Comparison Nucleus	The nucleus relative to which the cross-section data have been obtained. The reference given indicates which parameter values for the comparison nucleus have been used
abs.	Absolute measurement, without the use of a comparison nucleus
Ref.	Key to the list of references at the end of the tables
Remarks	The entries indicated by a letter or the symbol † are explained at the bottom of each page, the numerical entries at the end of each table

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Added in Proof

After completion of the manuscript it was discovered that the entries for 88Sr, 89Y, 90Zr and 92Mo (Ref. Si73c) and for 110Cd, 112Cd, 114Cd and 116Cd (Ref. Gi73) had been obtained using a faulty version of a phase-shift code. After correcting this code, dr. R.P. Singhal and dr. W.A. Gillespie have kindly reanalyzed their data. The correct results were then entered in the tables, which therefore differ from the values quoted in the references cited.

We have used this opportunity to add three recent papers to this note.

Table I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{\frac{1}{2}}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
1H	MI	0.81(4)				0.39-0.89	abs	Mu74	1
66Zn	2pF	3.991(27)	4.286(29)	0.595(11)		0.96-1.63	abs	Li73	
68Zn	2pF	3.979(31)	4.353(32)	0.567(14)		0.96-1.63	abs	Li73	

Remarks

1) In this experiment the recoil proton was observed.

Table V. Magnetization-Density-Distribution Parameters

Nucleus	μ [n.m.]	$\langle r^2 \rangle_M^{\frac{1}{2}}$ [fm]	a_o [fm]	R	R_{SPM}	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
13C	0.7024	2.80(4)	1.77(4)	-0.83(7)	-2.0	0.40-2.25	abs	La74	1

Remarks

1) Combined analysis, performed in Distorted Wave Born Approximation, of low- and high-energy data (La74, He70a).

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Mu74 J.J. Murphy, II, Y.M. Shin and D.M. Skopik, Phys. Rev. C9, 2125 (1974)

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{1/2}$ [fm]	c or a [fm]	z or α [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
n		0.3359(36)				0		Kr73	†,1
1H	MI	0.800(25)				0.98-1.33	abs	Fr66	†,a,2
		0.804(5)				0.55-3.30	abs	Bi71	a,3
	MI	0.81(2)				0.44-0.71	abs	Ak72	a,4
		0.85(2)				0.33-1.42	abs	Th72	a,5
		0.92(3)				0.36-1.45	abs	Bo74	6
2H		2.095(6)				0.22-0.71	1H(Vr64)	Be73a	†,a,7
3H	MI	1.70(5)				1.0 -2.83	1H(Vr64)	Co65	a
3He	MI	1.87(5)				1.0 -2.83	1H(Vr64)	Co65	†,a
		1.88(5)				0.5 -4.47	1H(Ja66)	MC70	8
4He	3pF	1.71	1.008(13)	0.327(2)	0.445(20)	0.7 -4.47	1H(Ja66)	Fr67	†,a
	MI	1.63(4)				0.14-0.53	1H(Fr66)	Er68	
	3pF	1.71(4)	0.964(12)	0.322(7)	0.517(16)	0.59-2.5	1H(Ja66)	MC74	57
6Li		2.54(6)				0.69-2.52	1H(Ja66)	Su67	†,a,9
		2.56(5)				0.56-3.66	1H(Ja66)	Li71	10
	MI	2.57(10)				0.09-0.90	12C(Si70b)	Bu72	
7Li	HO	2.39(3)	1.77(2)	0.327		0.69-2.62	1H(Ja66)	Su67	†,a
	MI	2.41(10)				0.09-0.90	12C(Si70b)	Bu72	
9Be	HO	2.50(9)	1.77(6)	0.631		0.15-0.53	12C(Fe73b)	Fe73a	†,11
	HO	2.519(12)	1.791(9)	0.611		0.26-0.70	abs	Ja72	
10B	HO	2.45(12)	1.71(8)	0.837		0.69-2.81	abs	St66	†,b
11B	HO	2.42(12)	1.69(8)	0.811		0.69-2.81	abs	St66	†,b
		2.37				0.61-1.76	abs	Ri71	b,12
12C	MHO	2.460(25)	1.649(8)	1.247(18)		1.05-4.01	1H(Ja66)	Si70b	†,13
	HO	2.454(8)	1.687(5)	1.067		0.18-0.70	abs	Ja72	
	MHO	2.44(2)	1.672(9)	1.150(20)		1.04-2.15	1H(Ja66)	Kl73	
	3pF	2.4550(24)	2.355(4)	0.5224(20)	-0.149(5)	0.25-2.3	abs	Me73a	d
	MIA	2.446(10)				0.25-2.3	abs	Me73a	
	HO	2.462(22)	1.692(15)	1.082		0.29-0.48	1H(Ja66)	Fe73b	
13C	MHO	2.440(25)	1.635(9)	1.403(16)		0.3 -3.5	1H(Ja66)	He70a	14
14C	MHO	2.56(5)	1.73(4)	1.38(12)		1.04-2.16	1H(Ja66)	Kl73	
14N	HO	2.58	1.76	1.234		0.86-1.62	1H(Ja66)	Da70	†,a,15
	HO	2.540(20)	1.729(14)	1.291		0.29-0.46	1H(Ja66)	Sc73a	
15N	MHO	2.65	1.81	1.250		0.86-1.62	1H(Ja66)	Da70	†,a,15
	3pF	2.70(3)	2.334(35)	0.498(5)	0.139(30)	0.87-2.61	1H(Ja66)	Ge72	16
	HO	2.580(26)	1.756(18)	1.290		0.22-0.46	14N(Sc73a)	Sc73a	
16O	HO	2.674(22)	1.805(15)	1.517		0.58-0.99	1H(Fr66)	Si70a	†
	3pF	2.730(25)	2.608(36)	0.513(5)	-0.051(20)	1.05-3.97	1H(Ja66)	Si70b)	13
	HO	2.718(21)	1.833(14)	1.544		0.29-0.46	1H(Ja66)	Sc73a	
17O	HO	2.662(26)	1.798(18)	1.498		0.58-0.99	1H(Ja66)	Si70a	
18O	HO	2.727(20)	1.841(14)	1.513		0.58-0.99	1H(Ja66)	Si70a	
	HO	2.789(27)	1.881(18)	1.544		0.22-0.48	16O(Sc73a)	Sc73a	

† Additional information, not tabulated, can be found in the following references:

n : Vr64, Du65, Du66, Hu66a, Hu66b, Ch66a, Gr66a, Gr66b, Bu68, Bu69, El69, Ga71, Ba72, Be73a, Ha73a.
1H : Bu61, Dr62, Le62, Be63, Ch63, Du63, Du65, Al66, Ba66, Ch66a, Ch66b, Gr66b, Ja66, Al67, Ba67a, Be67a, Go67, Be68, Ba70, Go70, Li70a, Be71a, Ha71, Ja71, Pr71, Ba73, Bo73b, Ki73, Si73e, Th74.
2H : MI57a, MI58, Be64a, Gr66a, El69, Ra73, Sk73.
3He: Be72a.
4He: Bl56, Ho56, MA56, Bu60, Re65, St69.
6Li: Bu58, Be65.
7Li: Be65.
9Be: Ho57, Me59, Ng64, Be67b, Be69, Be73b.
10B: Me59.
11B: Me59.
12C: Fr65, Eh59, Cr66, Af67, En67, Be71b.
14N: Me59, Bi64, Be65, Be71b.
15N: Pa68.
16O: Eh59, Me59, Cr66, Be71b.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{1/2}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
19F	2pF	2.900(15)	2.59(4)	0.564(14)		0.55-1.01	40Ca(He73)	Ha73b	
20Ne	2pF	3.040(25)	2.805(15)	0.571(5)		0.22-1.04	16O(Si70a)	Mo71	
	2pF	3.00(3)	2.74(3)	0.569		0.22-0.48	1H(Ja66)	Fe73a	e,17
22Ne	2pF	2.969(21)	2.782(12)	0.549(4)		0.2 -1.1	16O(Si70a)	Mo71	
23Na	UG	2.94(6)				0.4 -2.02	abs	Sa69a	b,18
24Mg	3pF	3.075(15)	3.108(33)	0.607(9)	-0.163(30)	0.58-1.99	12C(Si70b)	Av74	†,19
	2pF	3.032(28)	2.942(39)	0.538(15)		0.41-2.02	1H(Ho57)	Na72	20
	2pF	3.08(5)	2.99(5)	0.548(32)		0.20-1.15	12C(Ja72)	Le74	21
	3pF	2.985(30)	3.192(34)	0.604(6)	-0.249(20)	0.74-3.46	1H(Ja66)	Li74	22
25Mg	2pF	3.11(5)	2.76(5)	0.608(32)		0.20-1.15	12C(Ja72)	Le74	21
26Mg	2pF	3.06(5)	3.05(5)	0.524(32)		0.20-1.15	12C(Ja72)	Le74	21
27Al	2pF	3.06(9)	3.07(9)	0.519(26)		0.51-1.59	abs	Lo67	†
	2pF	3.05(5)	2.84(5)	0.569		0.23-0.59	12C(Fe73b)	Fe73a	e,23
28Si	2pF	3.10(5)	2.93(5)	0.569		0.23-0.58	12C(Fe73b)	Fe73a	†,e,f,23
	3pF	3.08(4)	3.30	0.545	-0.18	1.03-2.1	12C(Cr66)	Mu70	f
	MIA	3.078(30)				1.03-2.1	12C(Si70b)	Av74	f,24
	2pF	3.138(30)	3.106(30)	0.542(16)		0.41-2.02	1H(Ho57)	Na72	19
	3pG	3.106(30)	1.95(9)	2.076(10)	0.286(12)	0.74-3.71	1H(Ja66)	Li74	
	2pF	3.15(5)	3.14(6)	0.537(32)		0.2 -1.1	12C(Ja72)	Br74	
29Si	2pF	3.12(6)	3.17(8)	0.52(4)		0.2 -1.1	12C(Ja72)	Br74	
31P	2pF	3.24	3.21	0.56		0.63-1.58	abs	Ko65	
	3pF	3.19(3)	3.369(25)	0.582(6)	-0.173(24)	0.73-2.85	1H(Ja66)	Si72	25
	3pF	3.197(4)	3.353(8)	0.5789(19)	-0.160(8)	0.4 -2.3	12C(Me73a)	Me73b	d
	MIA	3.187(16)				0.4 -2.3	12C(Me73a)	Me73b	
32S	3pF	3.243(10)	3.503(16)	0.633(5)	-0.250(13)	0.64-2.26	12C(Si70b)	Av74	†,f,26
	MIA	3.263(20)				0.64-2.26	12C(Si70b)	Av74	f,26
	3pG	3.239(30)	2.54(9)	2.191(10)	0.160(12)	0.74-3.71	1H(Ja66)	Li74	f,22
	3pF	3.247(4)	3.458(8)	0.6098(19)	-0.208(7)	0.4 -2.3	12C(Me73a)	Me73b	d,f
	MIA	3.238(15)				0.4 -2.3	12C(Me73a)	Me73b	f
40A	2pF	3.47(4)	3.388(13)	0.612(11)		0.51-0.85	16O(Si70a)	Gr71	†
	2pF	3.42(4)	3.47(4)	0.569		0.29-0.49	1H(Ja66)	Fe73a	e,27
	3pF	3.48(4)	3.73(5)	0.62(1)	-0.19(4)	0.8 -1.8	12C(Si70b)	We74	
	MIA	3.48(8)				0.8 -1.8	12C(Si70b)	We74	
39K	UG	3.40(7)				0.4 -1.92	abs	Sa69a	b,f,28
	3pF	3.408(27)	3.743(25)	0.585(6)	-0.201(22)	0.64-3.43	1H(Ja66)	Si73a	f,29
40Ca	3pF	3.486	3.6685	0.5839	-0.1017	0.49-3.37	1H(Ja66)	Be67d	†,30
	3pF	3.452	3.725(15)	0.591(4)	-0.169(18)	0.70-2.25	1H(Ja66)	Fr68	31
	2pF	3.43(7)	3.51(7)	0.563		0.25-0.59	12C(En67)	Ei69	e,f
	3pF	3.482(25)	3.766(23)	0.586(5)	-0.161(23)	0.53-3.24	1H(Ja66)	Si73a	32
48Ca	3pF	3.470	3.7369	0.5245	-0.030	0.49-3.37	1H(Ja66)	Be67d	33
Ti	2pF	3.59(4)	3.75(4)	0.567		0.15-0.53	12C(Fe73b)	Fe73a	e,f,34

† Additional information, not tabulated, can be found in the following references:

24Mg: He56, Sa69b.
27Al: St67.
28Si: He56, Sa69c.
32S : He56, Lo64.
40A : He56.
40Ca: Ha56, Cr61, Cr65.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{1/2}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
51V	2pF	3.58(4)	3.94(3)	0.505(14)		0.56-1.79	12C(Si70b)	Pe73	†
	2pF	3.615(31)	3.91(4)	0.532(29)		0.23-0.78	12C(Ja72)	Go74	
Cr	2pF	3.656	3.975(25)	0.530(11)		0.40-1.25	abs	Be64b	f
55Mn	2pF	3.68(11)	3.89(12)	0.567		0.23-0.50	12C(Be71b)	Th69	e
Fe	2pF	3.74(11)	3.98(12)	0.569		0.23-0.59	12C(Fe73b)	Fe73a	e,f,35
54Fe	2pF	3.723(6)	4.012(7)	0.5339(25)		1.02-1.77	abs	Li72a	†,c
	3pG	3.690(10)	3.473(11)	2.280(3)	0.431(18)	0.51-2.22	12C(Me73a)	Wo73	36
56Fe	2pF	3.787(13)	3.971(13)	0.5935(46)		1.02-1.98	abs	Li72a	†,c
	3pG	3.737(10)	3.475(11)	2.330(3)	0.401(18)	0.51-2.22	12C(Me73a)	Wo73	36
58Fe	2pF	3.783(19)	4.027(19)	0.5757(71)		1.02-1.77	abs	Li72a	c
	3pG	3.779(25)	3.49(14)	2.363(12)	0.40(8)	0.51-1.25	12C(Me73a)	Wo73	36,37
59Co	2pF	3.80(5)	4.08(5)	0.569		0.23-0.56	12C(Fe73b)	Fe73a	†,e,35
Ni	2pF	3.81(8)	4.09(9)	0.569		0.23-0.59	12C(Fe73b)	Fe73a	e,f,35
58Ni	2pF	3.823(15)	4.140(17)	0.560(5)		0.68-1.61	abs	Kh70b	†,c
	2pF	3.783(10)	4.084(10)	0.5575(36)		1.02-1.98	abs	Li72a	c
	3pG	3.760(10)	3.603(11)	2.311(3)	0.414(18)	0.51-2.22	12C(Me73a)	Wo73	36
	3pF	3.764(10)	4.3092	0.5169	-0.1308	0.58-2.64	1H(Ja66)	Fi74a	38
60Ni	2pF	3.866(15)	4.150(17)	0.578(5)		0.68-1.61	abs	Kh70b	†,c
	2pF	3.812(30)	4.138(27)	0.554(11)		0.98-1.73	abs	Li72b	c
	3pG	3.792(10)	3.720(11)	2.330(3)	0.336(18)	0.51-2.22	12C(Me73a)	Wo73	36
	3pF	3.796(10)	4.4891	0.5369	-0.2668	0.52-2.28	1H(Ja66)	Fi74a	38
61Ni	3pF	3.806(10)	4.4024	0.5401	-0.1983	0.52-2.28	1H(Ja66)	Fi74a	38
62Ni	2pF	3.856(10)	4.148(11)	0.5703(36)		1.02-1.93	abs	Li72a	c
	3pG	3.828(10)	3.788(11)	2.345(3)	0.322(8)	0.51-2.22	12C(Me73a)	Wo73	36
	2pF	3.854(33)	4.223(37)	0.548(29)		0.23-0.78	12C(Ja72)	Go74	
	3pF	3.822(10)	4.4425	0.5386	-0.2090	0.52-2.28	1H(Ja66)	Fi74a	38
64Ni	2pF	3.907(26)	4.212(28)	0.578(7)		0.68-1.61	abs	Kh70b	†,c
	3pG	3.842(11)	3.904(12)	2.332(3)	0.280(20)	0.51-2.22	12C(Me73a)	Wo73	36,37
	3pF	3.845(10)	4.5211	0.5278	-0.2284	0.52-2.64	1H(Ja66)	Fi74a	38
Cu	2pF	3.88(5)	4.20(5)	0.569		0.23-0.59	12C(Fe73b)	Fe73a	e,f,35
63Cu	2pF	3.925(22)	4.214(26)	0.586(18)		0.23-0.78	12C(Ja72)	Go74	
65Cu	2pF	3.947(22)	4.271(25)	0.579(18)		0.23-0.78	12C(Ja72)	Go74	
Zn	2pF	3.93(5)	4.28(5)	0.569		0.23-0.59	12C(Fe73b)	Fe73a	e,f,35
64Zn	2pF	4.041(17)	4.265(16)	0.627(4)		0.87-1.87	abs	Af71	c
	2pF	3.943(25)	4.183(21)	0.603(8)		0.98-1.61	abs	Li72b	c
	2pF	3.965(17)	4.285(9)	0.584(9)		0.30-1.09	12C(Ja72)	Ne72	39
	3pG	3.918(11)	3.739(12)	2.457(3)	0.290(19)	0.51-2.22	12C(Me73a)	Wo73	36,37
66Zn	2pF	4.081(25)	4.291(22)	0.638(6)		0.87-1.87	abs	Af71	c
	2pF	3.977(20)	4.251(19)	0.599(6)		0.98-1.61	abs	Li72b	c
	2pF	4.009(15)	4.318(8)	0.595(8)		0.30-1.09	12C(Ja72)	Ne72	39

† Additional information, not tabulated, can be found in the following references:

51V : Ha56, Cr61.
54Fe: Be62.
56Fe: Be62.
59Co: Ha56, Cr61, Go63a.
58Ni: Af70.
60Ni: Af70.
64Ni: Af70.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{1/2}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
68Zn	2pF	3.996(16)	4.378(9)	0.569(9)		0.30-1.09	12C(Ja72)	Ne72	39
	3pG	3.956(13)	3.923(12)	2.450(3)	0.250(19)	0.51-2.22	12C(Me73a)	Wo73	36,37
70Zn	2pF	4.044(18)	4.409(10)	0.583(9)		0.30-1.09	12C(Ja72)	Ne72	39
	3pG	3.996(16)	3.919(16)	2.462(3)	0.317(25)	0.51-2.22	12C(Me73a)	Wo73	36,37
88Sr	3pG	4.26(1)	4.254(10)	2.548(6)	0.47(3)	0.71-2.65	1H(Ja66)	Al74	†
	2pF	4.17(2)	4.83(1)	0.496(11)		0.41-1.01	12C(Ja72)	Fi74b	
89Y	2pF	4.24	4.76(5)	0.571(29)		0.49-1.81	abs	Sh67a	†,c
	3pG	4.24(2)	4.45(3)	2.526(23)	0.25	0.41-1.15	12C(Ja72)	Si73c	d,56
	2pF	4.27(2)	4.86(1)	0.542(11)		0.41-1.01	12C(Ja72)	Fi74b	
90Zr	3pG	4.274(22)	4.434(20)	2.528(3)	0.350(25)	0.53-2.80	1H(Ja66)	Fa71	†,40
	3pG	4.25(7)	4.50(10)	2.53(7)	0.20(11)	0.64-1.86	12C(Si70b)	Ph72	
	3pG	4.265(4)	4.522(13)	2.5216(38)	0.245(17)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.244(26)				0.56-1.96	12C(Me73a)	Dr73	
	3pG	4.28(2)	4.46(5)	2.569(32)	0.250	0.40-1.15	12C(Ja72)	Si73c	d,56
91Zr	3pG	4.309(22)	4.325(20)	2.581(3)	0.433(25)	0.53-2.43	1H(Ja66)	Fa71	40
92Zr	3pG	4.300(22)	4.455(20)	2.550(3)	0.334(25)	0.53-2.43	1H(Ja66)	Fa71	40
94Zr	3pG	4.332(22)	4.494(20)	2.585(3)	0.296(25)	0.53-2.43	1H(Ja66)	Fa71	40
96Zr	3pG	4.396(22)	4.503(20)	2.602(3)	0.341(25)	0.89-2.80	1H(Ja66)	Fa71	40
93Nb	2pF	4.31	4.87(5)	0.573(29)		0.49-1.81	abs	Sh67a	c
92Mo	3pG	4.28(7)	4.61(10)	2.52(7)	0.19(11)	0.64-1.86	12C(Si70b)	Ph72	
	3pG	4.317(4)	4.538(13)	2.5445(27)	0.304(18)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.296(26)				0.56-1.96	12C(Me73a)	Dr73	
	3pG	4.34(2)	4.56(4)	2.606(23)	0.210	0.40-1.15	12C(Ja72)	Si73c	d,56
94Mo	3pG	4.358(4)	4.517(13)	2.5874(36)	0.330(18)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.334(26)				0.56-1.96	12C(Me73a)	Dr73	
96Mo	3pG	4.390(4)	4.534(14)	2.6235(36)	0.306(18)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.364(26)				0.56-1.96	12C(Me73a)	Dr73	
98Mo	3pG	4.423(4)	4.562(14)	2.6501(36)	0.297(18)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.391(26)				0.56-1.96	12C(Me73a)	Dr73	
100Mo	3pG	4.461(4)	4.559(14)	2.6723(36)	0.339(19)	0.56-1.96	12C(Me73a)	Dr73	d
	MIA	4.431(26)				0.56-1.96	12C(Me73a)	Dr73	
110Cd	2pF	4.58(1)	5.33(2)	0.535(7)		0.2 -1.1	12C(Ja72)	Gi73	
112Cd	2pF	4.61(1)	5.38(2)	0.532(9)		0.2 -1.1	12C(Ja72)	Gi73	
114Cd	2pF	4.63(1)	5.40(2)	0.537(9)		0.2 -1.1	12C(Ja72)	Gi73	
116Cd	2pF	4.64(1)	5.42(2)	0.532(9)		0.2 -1.1	12C(Ja72)	Gi73	
In	2pF	4.50(9)	5.24(10)	0.52(5)		0.47-1.56	197Au(Ha56)	Ha56	†,f
112Sn	2pF	4.655(23)	5.375(26)	0.560(10)		0.49-1.40	abs	Kh70b	c
	3pG	4.586(5)	4.962(7)	2.638(3)	0.285(12)	0.64-2.37	1H(Ja66)	Fi72	41
114Sn	3pG	4.602(5)	4.971(7)	2.636(3)	0.320(12)	0.64-2.37	1H(Ja66)	Fi72	41

† Additional information, not tabulated, can be found in the following references:

88Sr: He56.
89Y : Pe68.
90Zr: Be70b.
In: Cr61, Ke63.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$\langle r^2 \rangle^{1/2}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
116Sn	2pF	4.551	5.275(25)	0.539(11)		0.46-1.08	abs	Ba67b	
	2pF	4.62	5.28(3)	0.580(6)		0.35-0.59	1H(point)	Cu69	42
	2pF	4.673(16)	5.416(19)	0.552(6)		0.84-1.98	abs	Li72c	c
	3pG	4.619(5)	5.062(7)	2.625(3)	0.272(12)	0.64-2.65	1H(Ja66)	Fi72	41
117Sn	3pG	4.625(5)	5.058(7)	2.625(3)	0.295(12)	0.64-2.37	1H(Ja66)	Fi72	41
118Sn	2pF	4.64	5.30(3)	0.583(6)		0.35-0.59	1H(point)	Cu69	42
	2pF	4.679(16)	5.412(18)	0.560(5)		0.49-1.40	abs	Kh70b	c
	2pF	4.676(17)	5.442(21)	0.543(7)		0.84-1.75	abs	Li72c	c
	3pG	4.634(5)	5.072(7)	2.623(3)	0.304(12)	0.64-2.37	1H(Ja66)	Fi72	41
119Sn	3pG	4.639(5)	5.100(7)	2.618(7)	0.290(12)	0.64-2.37	1H(Ja66)	Fi72	41
120Sn	2pF	4.640	5.315(25)	0.576(11)		0.46-1.08	abs	Ba67b	
	2pF	4.64	5.32	0.576		0.35-0.59	1H(point)	Cu69	42
	3pG	4.646(5)	5.110(7)	2.619(3)	0.292(12)	0.64-2.37	1H(Ja66)	Fi72	41
122Sn	3pG	4.658(5)	5.088(7)	2.611(3)	0.378(12)	0.64-2.37	1H(Ja66)	Fi72	41
124Sn	2pF	4.666	5.440(30)	0.539(11)		0.46-1.08	abs	Ba67b	
	2pF	4.64	5.44(3)	0.528(6)		0.35-0.59	1H(point)	Cu69	42
	2pF	4.695(17)	5.490(21)	0.534(7)		0.84-1.75	abs	Li72c	c
	3pG	4.670(5)	5.150(7)	2.615(3)	0.311(12)	0.64-2.65	1H(Ja66)	Fi72	41
Sb	2pF	4.63(9)	5.32(11)	0.57(6)		0.56-1.31	197Au(Ha56)	Ha56	†,f
138Ba	3pG	4.836	5.3376	2.6776	0.3749	0.56-2.84	1H(Ja66)	He70b	43
La	2pF	4.85	5.71(6)	0.535(27)		0.74-1.87	abs	Sh67b	c,f
142Nd	3pG	4.888	5.3120	2.7311	0.4378	0.57-2.83	1H(Ja66)	He70b	43
	2pF	4.863(34)	5.774(26)	0.513(16)		0.23-0.59	12C(Ja72)	Ca73	44
	3pF	4.920	5.6135	0.5868(24)	0.096(14)	0.55-2.97	1H(Ja66)	He71	45
	2pF	4.913	5.6838	0.5868(30)		0.55-2.97	1H(Ja66)	He71	46
	2pF	4.993(35)	5.839(33)	0.569(18)		0.22-0.73	12C(Ja72)	Ma74	
144Nd	2pF	4.926	5.6256	0.6178(30)		0.55-2.97	1H(Ja66)	He71	46
146Nd	2pF	4.970	5.6541	0.6321(30)		0.55-2.97	1H(Ja66)	He71	†,46
	2pF	4.993(37)	5.867(32)	0.556(20)		0.22-0.73	12C(Ja72)	Ma74	
148Nd	2pF	5.002	5.6703	0.644(5)		0.55-2.97	1H(Ja66)	He71	46
150Nd	2pF	5.048	5.7185	0.651(7)		0.55-2.97	1H(Ja66)	He71	†,46
	2pF	5.015(37)	5.865(35)	0.571(18)		0.22-0.73	12C(Ja72)	Ma74	
148Sm	2pF	4.989(37)	5.771(31)	0.596(15)		0.25-0.59	12C(Ja72)	Ca73	
152Sm	2pF	5.0922	5.8044	0.581(15)		0.37-1.02	12C(Si70b)	Be72b	47
154Sm	2pF	5.1257	5.9387	0.522(15)		0.37-1.02	12C(Si70b)	He73	47
165Ho	2pF	5.23	6.18	0.57		0.54-1.43	1H(Ja66)	Sa67	48
	2pF	5.19	6.12	0.57		0.50-1.45	1H(Ja66)	Uh71	48
181Ta	2pF	5.48	6.38	0.64		0.56-1.42	abs	Do57	†,49
184W	2pF	5.42(7)	6.51(7)	0.535(36)		0.25-0.60	6Li(Li71)	Ka73	†
186W	2pF	5.40(4)	6.58(3)	0.480(23)		0.25-0.60	6Li(Li71)	Ka73	

† Additional information, not tabulated, can be found in the following references:

Sb: Cr61.
146Nd: Ma71.
150Nd: Ma71.
Hf: Ha56, Do57.
181Ta: Ke63.
W : Pi55, Ha56, Do57.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Nucleus	Model	$<r^2>^{1/2}$ [fm]	c [fm]	z [fm]	w	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
197Au	2pF	5.33(5)	6.38(6)	0.535(27)		0.56-1.42	abs	Ha56	
		5.27(9)				0.08-0.27	abs	Be60	50
Pb	2pF	5.50(6)	6.69(8)	0.494(39)		0.07-0.53	12C(Ja72)	Ni69	†,f,51
206Pb	2pF	5.509(29)	6.61(5)	0.545(8)		0.22-0.88	12C(Ja72)	Ja73	
207Pb	2pF	5.513(32)	6.62(6)	0.546(10)		0.22-0.88	12C(Ja72)	Ja73	
208Pb	3pG	5.501	6.3032	2.8882	0.3379	0.44-2.73	1H(Ja66)	He69	†,52
	MIA	5.498(10)				0.44-2.73	1H(Ja66)	Dr74	53
	3pG	5.499	6.39(5)	2.86(3)	0.24(12)	0.48-1.64	12C(Si70b)	Fr72b	54
	MIA	5.49(10)				0.48-1.64	12C(Si70b)	Fr72b	
	2pF	5.521(29)	6.624(35)	0.549(8)		0.22-0.88	12C(Ja72)	Ja73	
209Bi	2pF	5.51(5)	6.75(7)	0.468(39)		0.07-0.53	12C(Ja72)	Ni69	†,51
	3pG	5.521(2)	6.315(10)	2.881(8)	0.39(6)	0.7 -2.8	1H(Ja66)	Si73b	55
232Th	2pF	5.7734	6.7915	0.571(15)		0.37-1.02	12C(Si70b)	He73	†,47
238U	2pF	5.8434	6.8054	0.605(16)		0.37-1.02	12C(Si70b)	He73	†,47

† Additional information, not tabulated, can be found in the following references:

Pb: Mi57b, Fi64.
208Pb: Be67e.
209Bi: Ha56, Be60, Cr61, Go63a, He63, Br66.
232Th: Ha56, Do57.
238U : Ha56, Do57.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation, using an effective q-value.
c) Analysis performed using the High Energy Approximation (Pe66).
d) Only statistical errors quoted, corresponding to one standard deviation.
e) The value of z was fixed in the analysis.
f) Using a target of natural isotopic composition.

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TABLE I. Charge-Density-Distribution Parameters

Remarks

1) Following Hofstadter and Collard (Ho67) the tabulated value for $\langle r^2\rangle^{1/2}$ is formally obtained from the slope of the neutron charge form factor at $q^2 = 0$ as determined from the scattering of slow neutrons by atomic electrons. Further information on neutron form factors, obtained from electron scattering from 2H and 3H, is given in the list of additional references.
2) In this experiment the recoil proton was observed.
3) Result of an analysis with the dipole model, using all data available up till May 1970 for $q^2 < 10$ fm^{-2} (Li61, O161, Dr62, Le62, Be63, Ch63, Dr63, Du63, Du64, A166, Ch66b, Fr66, Ja66, A167, Ba67a, Be67a, Go70). Bilenkaya et al also present the results of analyses of more extended q-ranges (up till q = 15 fm^{-1}), including data from refs. Be68, Co68 and Li70a.
4) Result of an analysis using the dipole model with a free normalization for the data, which have been obtained by observing the recoil proton.
5) Result of an analysis of all available data below $q^2 = 2$ fm^{-2} (Bu61, Dr62, Le62, Du65, Fr66, Ja71).
6) In a private communication the authors have given preference to the result obtained from an analysis with a four-pole model of three different sets of data (Be71a, Ha71, Bo74) (see also ref. Si73e).
7) Value obtained from an analysis of the elastic electron-deuteron scattering data using several models for the deuteron wave function.
8) The data could be fitted excellently out to $q^2 = 8$ fm^{-2} using a charge distribution given by

$$\rho_o(r) = \frac{Z}{8\pi^{3/2}} \left\{ \frac{1}{a^3}\exp(-r^2/4a^2) - \frac{c^2(6b^2-r^2)}{4b^7}\exp(-r^2/4b^2) \right\}$$

A fit to the complete data set was obtained by adding an oscillatory modification $\Delta\rho(r)$ to $\rho_o(r)$

$$\Delta\rho(r) = A\rho_o(0) \left\{ \frac{\sin(q_o r)}{q_o r} + \frac{p^2}{2q_o^2}\cos(q_o r) \right\} \exp(-p^2r^2/4)$$

the Fourier transform of a form factor modification $\Delta F \propto \exp(-(q-q_o)^2/p^2)$. The best fit results are: a = 0.675(8) fm, b = 0.836(32) fm, c = 0.366(25) fm, A = -0.140(17), p = 0.90(16) fm^{-1} and q_o = 3.98(9) fm^{-1}.
9) Analysis using a charge distribution as defined in remark 8 (without the modification), yielding a = 0.933(3) fm, b = 1.30(6) fm and c = 0.45(3) fm.
10) Analysis using a charge distribution as defined in remark 8 (with modification), yielding a = 0.928(3) fm, b = 1.26(9) fm, c = 0.48(4) fm, A = -0.029(7), p = 0.70(29) fm^{-1} and q_o = 3.11(20) fm^{-1}.
11) Correcting the data of ref. Be67c for the new value of the 12C radius.
12) The data were analyzed using nuclear wave functions obtained by extending the Nilsson model to include the single-particle orbitals admixtures from higher major shells.
13) In the analysis of the 12C data two modifications were added to the MHO charge distribution: a tail modification of a Gaussian form in order to approximate the 3pF density in the tail region and an oscillatory modification corresponding to the Fourier transform of a damped sine wave (see remark 38). In the case of 16O the inclusion of an oscillatory modification - of the form of a damped sine wave (see remark 25) - was sufficient to fit the complete data set.
14) Here also an exponential tail modification was added to the MHO charge distribution. Only the amplitude of the tail modification was fitted as a free parameter, the other two parameters were taken from the 12C results of ref. Si70b.
15) Results of a fit to the data up till the first diffraction minimum without applying corrections for elastic scattering from the M1 and C2 moments.
16) Reanalysis of the data presented in ref. Da69.
17) Reanalysis of the data presented in ref. Fr72a. There, data had also been taken with 16O (Be71b) as a reference nucleus. These data were corrected for the new 16O radius.
18) The data were analyzed using the Uniform Gaussian model, yielding parameter values R = 3.13(6) fm and g = 0.96(5) fm.

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TABLE I. Charge-Density-Distribution Parameters

19) Correcting the data presented in ref. Ju70 for the new value of the 12C radius.
20) Data were also taken with 12C (Ho57) as a comparison nucleus. The tabulated values were obtained by averaging the results of separate fits to the data taken at 183 MeV and at 250 MeV.
21) Reanalysis of the data presented in ref. Cu72.
22) The oscillatory modification defined in remark 8 was included in the analysis of the 24Mg and the 32S data. The best fit results were: A = -0.076, $p = 0.51\ fm^{-1}$ and $q_o = 2.49\ fm^{-1}$ for 24Mg and A = 0.021, $p = 0.50\ fm^{-1}$ and $q_o = 2.83\ fm^{-1}$ for 32S.
23) Correcting the data presented in ref. Be70a for the new value of the 12C radius.
24) Correcting the data presented in ref. Mu70 for the new value of the 12C radius.
25) In this analysis an oscillatory modification of the form $\Delta\rho = A\rho_o(0)\exp(-p^2r^2/4)\sin(q_or)/(q_or)$ was used, yielding parameter values A = -0.034(8), $p = 0.51(11)\ fm^{-1}$ and $q_o = 2.48(7)\ fm^{-1}$.
26) Correcting the data presented in ref. Hu70 for the new value of the 12C radius.
27) Reanalysis of the data presented in ref. Sc71. There, data had also been taken with 4He (Er68) and 12C (Be71b) as comparison nuclei. The latter data were corrected for the new value of the 12C radius.
28) The data were analyzed using the Uniform Gaussian model, yielding parameter values R = 3.83(8) fm and g = 0.96(5) fm.
29) Analysis including an oscillatory modification as defined in remark 25, yielding A = 0.086(7), $p = 0.43(4)\ fm^{-1}$ and $q_o = 3.14(6)\ fm^{-1}$.
30) Analysis including an oscillatory modification as defined in remark 8, yielding A = 0.047, $p = 0.5\ fm^{-1}$ and $q_o = 3\ fm^{-1}$.
31) The tabulated values present the results of a fit to the 250 MeV data only. A reanalysis of these data, presented in ref. We74, yielded essentially identical values, albeit with different errors.
32) Analysis including an oscillatory modification as defined in remark 25, yielding A = 0.0814(8), $p = 0.43(4)\ fm^{-1}$ and $q_o = 3.14(5)\ fm^{-1}$. The data of ref. Be67d and previously unpublished data taken by J. Heisenberg, J. McCarthy and I. Sick were included in the analysis.
33) Analysis including an oscillatory modification as defined in remark 8, yielding A = 0.082, $p = 0.5\ fm^{-1}$ and $q_o = 3\ fm^{-1}$.
34) Correcting the data presented in ref. En66 for the new value of the 12C radius.
35) Correcting the data presented in ref. Th70 for the new value of the 12C radius.
36) The results are preliminary. The fits deviate in the diffraction minima and for q-values greater than 2 fm^{-1}. Only the statistical errors are quoted, one standard deviation for c, t and w, two standard deviations for the rms radius.
37) Measurements not completed.
38) The data were analyzed simultaneously with the results of muonic atom and optical isotope shift experiments. An oscillatory modification corresponding to the Fourier transform of a damped sine wave $\Delta F = A\exp\{-(q-q_o)^2/p^2\}\sin\{2\pi(q-q_o)/\lambda\}$ was also included in the analysis.
39) The data have been corrected by the present authors for the new value of the 12C radius.
40) The data were analyzed with several different models for the charge distribution. In most cases an oscillatory modification as defined in remark 38 was required to describe the data at high q-values adequately. Only the 3pG model gave an adequate fit to the entire data set without the addition of a modification.
41) The data were analyzed simultaneously with the results of muonic atom and optical isotope shift experiments. An oscillatory modification as defined in remark 38 was included in the analysis. The same parameter values could be used for all isotopes.
42) The form factor of the proton - the comparison nucleus - was assumed to be 1 over the q-range studied. No errors were assigned to the 120Sn results because of the poor quality of the fit.
43) Analysis including an oscillatory modification as defined in remark 8, yielding A = 0.13, $p = 0.25\ fm^{-1}$ and $q_o = 2.55\ fm^{-1}$ for the Ba as well as the Nd data.
44) Reanalysis of the data presented in ref. Ma71. The data were corrected for the new value of the 12C radius and the cross-section normalization was determined from the data below the first diffraction region, omitting the 15 MeV point from the analysis.

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TABLE I. Charge-Density-Distribution Parameters

45) Analysis including an oscillatory modification, corresponding to the Fourier transform of
$\Delta F = A\{B + \sin\{2\pi(q-q_o)/\lambda\}\ \exp\{-(q-q_o)^2/p^2\}\}$

46) The rms radius of 150Nd as determined from muonic X-ray data combined with the radius differences as determined from K_α X-ray data were used as constraints in the analysis. The results give an adequate description of the data for all isotopes, but 142Nd.

47) The elastic electron scattering data were analyzed simultaneously with data for electroexcitation of the ground-state rotational band using a deformed Fermi distribution

$$\rho(r,\theta) = \rho_o/(1+\exp\{(r-R(\theta))/z\})$$

with $R(\theta) = c\{1 + \beta_2 Y_{20}(\theta) + \beta_4 Y_{40}(\theta) + \beta_6 Y_{60}(\theta)\}$

The values for $\langle r^2\rangle^{\frac{1}{2}}$, β_2 and β_6 were taken from other types of experiments, leaving β_4 and z as free parameters. The values for β_2, β_4 and β_6, either used in or yielded by the analysis are respectively:
0.287(3), 0.070(3) and -0.012(152Sm); 0.3106, 0.087(2) and -0.018(154Sm); 0.2372, 0.105(2) and 0.0(232Th) and 0.2601, 0.095(2) and 0.0(238U).

48) Cross sections were measured for electron scattering from randomly oriented and aligned 165Ho nuclei. The tabulated values present the results of an analysis of the data for randomly orientated nuclei with the 2pF distribution, after subtracting the scattering from the quadrupole moment.

49) Analysis of the data presented in ref. Ha56, using a deformed 2pF distribution $\rho(r,\theta) = \rho(r(1-\alpha P_2(\cos\theta))$. The tabulated values are for a 2pF distribution which gives a good approximation to the monopole term of the deformed distribution.

50) Analysis using a uniform charge distribution.

51) Data have also been taken with 9Be (Be67c) as a comparison nucleus. The data have been corrected by the present authors for the new values of the 9Be and 12C radii.

52) Data analyzed simultaneously with muonic X-ray data, including an oscillatory modification as defined in remark 45.

53) Analysis of the data presented in ref. He69. An analysis using Fourier transforms yielded $\langle r^2\rangle^{\frac{1}{2}} = 5.514(28)$ fm.

54) The rms radius value determined from muonic X-ray data was used as a constraint in the analysis.

55) The value of the 0.8th moment of the charge distribution from muonic X-ray data was used as a constraint. An oscillatory modification as defined in remark 45 was included in the analysis.

56) In a private communication the authors gave preference to the results obtained using the 3pG model for ease of comparison with the other tabulated results. The value of w was fixed in the analysis. The errors were obtained by assuming the same percentage errors as yielded by the analysis with the 2pF model.

57) Analysis including the data presented in ref. Fr67.

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TABLE II. Differences in Charge-Density-Distribution Parameters between Isotopes

Isotope Pair	Model	$\Delta\langle r^2\rangle^{\frac{1}{2}}$ [fm]	Δc [fm]	Δz [fm]	Δw	q-range [fm^{-1}]	Ref.	Remarks
7-6 Li	MI	-0.08(2)				0.51-1.27	Be65	1,2
	MI	-0.13(2)				0.35-0.71	Su67	1,2
	MI	-0.003(20)				0.36-0.78	Ni71	
13-12 C	HO	-0.10(2)				0.70-1.71	Cr67	1,3
	MHO	-0.023(10)				0.30-1.50	He70a	
	HO	-0.06(5)				0.26-1.23	Ya71	1,3
	HO	-0.012(19)				0.26-0.55	Be71b	
14-12 C	MHO	0.12(5)				1.04-2.16	Kl73	
15-14 N	HO	0.040(12)				0.22-0.46	Sc73a	
17-16 O	HO	-0.013(15)				0.39-0.99	Si70a	3
18-16 O	HO	0.067(16)				0.76-1.23	La61	1
	HO	0.053(12)				0.47-0.99	Si70a	
	HO	0.070(11)				0.22-0.48	Sc73a	
22-20 Ne	2pF	-0.073(27)				0.22-1.04	Mo71	
25-24 Mg	2pF	0.063(32)	-0.276(36)	0.082(23)		0.20-1.15	Le74	4
26-24 Mg	UG	-0.05(4)				0.69-1.40	Kh70a	5
	2pF	-0.018(32)	0.055(36)	-0.021(23)		0.20-1.15	Le74	4
42-40 Ca	3pF	0.030	0.052	0.006	-0.014	0.55-1.70	Fr68	
44-40 Ca	3pF	0.028	0.072	-0.014	0.007	0.70-1.79	Fr68	†
48-40 Ca	3pF	-0.0107	0.069(17)	-0.060(18)	0.072(13)	0.49-2.53	Fr68	†
	2pF	-0.04(7)	0.16(11)	-0.065		0.13-0.059	Ei69	6
48-46 Ti	2pF	-0.005(27)	-0.01(4)	0		0.22-0.57	Th67	6
	2pF	-0.015(10)	0.055(20)	-0.025(10)		0.55-1.11	Ro71	
	3pF	0.003(15)	-0.0076	-0.0293	0.0624	0.55-2.42	He72	
50-46 Ti	2pF	0.003(21)	0.005(33)	0		0.22-0.57	Th67	6
	2pF	-0.030(15)	0.090(25)	-0.045(15)		0.55-1.11	Ro71	
50-48 Ti	2pF	-0.020(10)	0.045(15)	-0.025(10)		0.55-1.11	Ro71	
	3pF	-0.016(15)	-0.0061	-0.0216	0.0380	0.55-2.49	He72	
56-54 Fe	2pF	0.069(14)	-0.052(17)	0.046(5)		1.02-1.77	Li72a	7
58-56 Fe	2pF	0.004(18)	0.092(20)	-0.026(6)		1.02-1.77	Li72a	7
60-58 Ni	2pF	0.051	0.062(18)	0.000(5)		1.05-1.61	Kh70b	†,7
62-58 Ni	2pF	0.061(8)	0.081(9)	0.006(3)		1.02-1.93	Li72a	7
64-58 Ni	2pF	0.106	0.095(18)	0.010(5)		1.05-1.61	Kh70b	7
64-60 Ni	2pF	0.055	0.044(16)	0.006(5)		1.05-1.61	Kh70b	7
65-63 Cu	2pF	0.024(9)	0.055(14)	-0.006(8)		0.29-0.88	Go74	
66-64 Zn	2pF	0.039(7)	0.036(5)	0.008(4)		0.30-1.09	Ne72	
	2pF	0.025(13)	0.048(13)	-0.003(3)		0.98-1.61	Li72b	7
68-66 Zn	2pF	-0.016(9)	0.059(5)	-0.029(5)		0.30-1.09	Ne72	
70-68 Zn	2pF	0.047(15)	0.032(10)	0.014(8)		0.30-1.09	Ne72	
94-92 Mo		0.041(5)				0.56-1.96	Dr73	8
96-94 Mo		0.028(5)				0.56-1.96	Dr73	8
98-96 Mo		0.029(5)				0.56-1.96	Dr73	8
100-98 Mo		0.039(5)				0.56-1.96	Dr73	8
118-112Sn	2pF	0.019	0.021(20)	0.000(7)		0.82-1.40	Kh70b	7
118-116Sn	2pF	-0.004(6)	0.025(6)	-0.013(2)		0.84-1.75	Li72c	7
124-116Sn	2pF	0.015(7)	0.069(7)	-0.020(7)		0.84-1.75	Li72c	7
124-118Sn	2pF	0.019(8)	0.045(9)	-0.007(3)		0.84-1.75	Li72c	7
146-142Nd	2pF	-0.10				0.24-0.59	Ca73	9
	2pF	0.0527(36)	0.018(26)	0.025(11)		0.22-0.73	Ma74	10
150-142Nd	2pF	0.08				0.24-0.59	Ca73	9
	2pF	0.115(5)	0.078(27)	0.041(14)		0.22-0.73	Ma74	10
150-146Nd	2pF	0.067(4)	0.046(27)	0.023(14)		0.22-0.73	Ma74	10
150-148Sm	2pF	0.03(7)				0.25-0.59	Ca73	

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TABLE II. Differences in Charge-Density-Distribution Parameters between Isotopes

Isotope Pair	Model	$\Delta\langle r^2\rangle^{\frac{1}{2}}$ [fm]	Δc [fm]	Δz [fm]	Δw	q-range [fm^{-1}]	Ref.	Remarks
152-148Sm	2pF	0.17(7)				0.25-0.59	Ca73	
207-206Pb	2pF	0.005(7)	0.008(16)	0.001(4)		0.22-0.88	Ja73	
208-206Pb	2pF	0.013(4)	0.010(9)	0.0039(25)		0.22-0.88	Ja73	
208-207Pb	2pF	0.008(7)	0.001(15)	0.005(4)		0.22-0.88	Ja73	†

† Additional information, not tabulated, can be found in the following references:

44-40Ca: Ho65.

48-40Ca: Oo66.

60- 58Ni: Ha57.

208-207Pb: Pe65.

Remarks:

1) Analysis performed in Plane Wave Born Approximation.
2) No corrections applied for the scattering from the C2 or higher charge multipole moments.
3) No corrections applied for the magnetic contribution to the elastic scattering.
4) Reanalysis of the data presented in ref. Cu72.
5) Analysis performed in Modified Born Approximation. The parameter differences obtained for the Uniform Gaussian model were ΔR = 0.03(2) fm and Δg = -0.07(4) fm.
6) The value of Δz was fixed in the analysis.
7) Analysis performed using the High Energy Approximation (Pe66).
8) Model-independent analysis of cross section ratios using a Fourier-Bessel expansion for $\rho(\dot{r})$ (Dr74). The quoted errors include statistical and model-dependent contributions.
9) Reanalysis of the data presented in Ma71.
10) Data analyzed simultaneously with K_α X-ray data.

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TABLE III. Differences in Charge-Density-Distribution Parameters between Neighboring Nuclei (not Isotopes)

Nuclear Pair	Model	$\Delta\langle r^2\rangle^{1/2}$ [fm]	Δc [fm]	Δz [fm]	Δw	q-range [fm^{-1}]	Ref.	Remarks
16O - 14N	HO	0.170(19)				0.29-0.48	Sc73a	
20Ne- 16O	2pF	0.279(20)				0.22-0.48	Fr72a	
46Ti- 45Sc	2pF	0.04(5)	0.06(8)	0		0.29-0.59	Th70	1
48Ti- 40Ca	3pF	0.097	0.179	-0.022	0.026	0.42-1.79	Fr68	
51V - 50Ti	2pF	0.06(5)	0.10(8)	0		0.29-0.59	Th70	1
58Ni- 54Fe	2pF	0.050(8)	0.064(8)	0.002(3)		1.02-1.77	Li72a	2
58Ni- 56Fe	2pF	-0.022(13)	0.107(14)	-0.046(4)		1.02-1.98	Li72a	†,2
58Ni- 58Fe	2pF	-0.026(12)	0.005(14)	-0.016(4)		1.02-1.77	Li72a	2
64Zn- 60Ni	2pF	0.132(20)	0.033(20)	0.052(5)		0.98-1.61	Li72b	2
66Zn- 60Ni	2pF	0.157(20)	0.082(19)	0.049(4)		0.98-1.61	Li72b	2
90Zr- 88Sr	2pF	0.042(12)	0.037(25)	0.009(7)		0.24-1.08	Si73	3
	3pG	0.049(4)	0.090(18)	0.042(4)	-0.071(27)	0.5 -2.0	Sc73b	3
	MIA	0.053(17)				0.5 -2.0	Sc73b	
		0.060(8)				0.5 -2.0	Sc73b	4
92Mo- 90Zr	3pG	0.054(22)	0.035(50)	0.01(3)	0.07(5)	0.64-1.86	Ph72	
		0.050(5)				0.56-1.96	Dr73	4
209Bi-208Pb	3pG	0.021	0.029	-0.007	0.026	0.7 -2.8	Si73b	5

† Additional information, not tabulated, can be found in reference Ha57.

Remarks:

1) The value of Δz was fixed in the analysis.
2) Analysis performed using the High Energy Approximation (Pe66).
3) Only statistical errors quoted.
4) Model-independent analysis using a Fourier-Bessel series expansion for $\rho(r)$ (Dr74). The quoted errors include statistical and model-dependent contributions.
5) The difference in the 0.8th moments of the charge distributions from muonic X-ray data was used as a constraint. A slightly better fit to the data was obtained by adding a $1h_{9/2}$ shell model wave function to the 3pG distribution for 209Bi.

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TABLE IV. Charge-Density Distributions from Model-Independent Analyses

Nucleus	3He	3He	4He	4He	12C	32S
Reference	Si73d	He74	Si73d	Bo73a	Si74	Si74
Method	SOG Γ=1.45 fm	Hermite exp. ass.	SOG Γ=1.35 fm	cosine exp. ass.	SOG Γ=1.63 fm	SOG Γ=1.85 fm
Data	MC70	MC70	Er68,Fr67,MC74	Fr67	Ja72,Si70b	Li74 [1]
$\langle r^2\rangle^{1/2}$ [fm]	1.839(31)		1.672(26)		2.468(16)	3.250(15)
R_k [fm]					3.178(18)	4.169(15)
r [fm]	$\rho(r)$ [e fm^{-3}]					
0.0	0.1049(14)	0.104(8)	0.1112(27)	0.110(10)	0.0809(27)	0.0916(31)
0.5	0.1006(10)	0.1005(19)	0.1115(13)	0.1080(28)	0.0831(14)	0.0905(15)
1.0	0.0759(9)	0.0766(11)	0.0882(11)	0.0854(16)	0.0832(13)	0.0880(10)
1.5	0.0388(5)	0.0385(7)	0.0438(5)	0.0432(11)	0.0732(10)	0.0837(5)
2.0	0.0154(2)	0.0155(5)	0.0150(2)	0.0150(8)	0.0537(6)	0.0773(7)
2.5	0.00622(5)	0.00643(33)	0.00458(8)	0.0052(5)	0.0320(4)	0.0666(4)
3.0	0.00219(6)	0.00204(22)	0.00119(8)	0.00136(38)	0.0154(2)	0.0512(2)
3.5	0.00055(7)	0.00069(19)	0.00023(7)	0.00031(28)	0.00618(14)	0.0338(2)
4.0	0.00012(6)	0.00010(15)	0.00005(4)	0.00002(18)	0.00213(8)	0.0189(1)
4.5	0.00003(3)	0.00008(9)	0.00002(2)	0.00000(18)	0.00068(5)	0.0090(2)
5.0	0.00001(1)	0.00000(6)			0.00020(3)	0.0037(2)
5.5					0.00006(2)	0.00135(9)
6.0					0.00003(2)	0.00046(8)
6.5					0.00001(1)	0.00013(4)
7.0						0.00005(2)
7.5						0.00002(2)

Nucleus	39K	40Ca	40Ca	48Ca	208Pb
Reference	Si73d	Si73d	Si73d	Si73d	Dr74
Method	SOG Γ=1.95 fm	SOG Γ=1.95 fm	SOG Γ=1.95 fm	SOG Γ=1.95 fm	Fourier-Bessel q^{-4} ass.
Data	Si73a [1]	Si73a,Be67d [1,2]	Si73a,Be67d [1,3]	Fr68,Be67d [1,4]	He69
$\langle r^2\rangle^{1/2}$ [fm]	3.429(18)	3.476(7)	3.476(7)	3.467(7)	5.514(28)
R_k [fm]	4.408(17)	4.456(6)	4.456(6)	4.450(6)	
r [fm]	$\rho(r)$ [e fm^{-3}]				
0.0	0.0921(13)	0.0918(12)	0.0872(12)	0.0813(16)	0.0615(27)
0.5	0.0894(8)	0.0886(6)	0.0863(7)	0.0796(11)	0.0611(19)
1.0	0.0835(6)	0.0832(5)	0.0839(6)	0.0766(8)	0.0603(11)
1.5	0.0799(4)	0.0800(5)	0.0807(5)	0.0748(6)	0.0599(10)
2.0	0.0767(5)	0.0776(5)	0.0773(5)	0.0738(5)	0.0603(8)
2.5	0.0704(5)	0.0718(4)	0.0718(4)	0.0706(4)	0.0612(8)
3.0	0.0582(4)	0.0602(3)	0.0605(3)	0.0614(3)	0.0620(6)
3.5	0.0421(2)	0.0445(2)	0.0445(2)	0.0466(2)	0.0624(5)
4.0	0.0260(2)	0.0280(2)	0.0279(2)	0.0296(2)	0.0628(4)
4.5	0.0133(1)	0.0147(1)	0.0148(1)	0.0153(2)	0.06288(36)
5.0	0.00575(15)	0.00659(15)	0.0066(1)	0.0065(2)	0.06155(27)
5.5	0.00221(15)	0.00265(8)	0.00265(8)	0.0023(1)	0.05674(21)
6.0	0.00084(7)	0.00097(7)	0.00095(7)	0.00077(8)	0.04732(17)
6.5	0.00033(5)	0.000335(35)	0.00033(3)	0.00022(4)	0.03446(16)
7.0	0.00012(2)	0.000115(15)	0.00012(2)	0.00008(2)	0.02136(14)
7.5	0.00006(3)	0.000055(20)	0.000055(20)		0.01109(13)
8.0	0.000033(17)	0.000028(18)	0.000027(17)		0.00486(12)
8.5					0.00189(11)
9.0					0.00067(11)
9.5					0.00020(11)
10.0					0.00003(9)

1) Data analyzed simultaneously with muonic X-ray data.
2) The statistical errors of the data taken above the third diffraction minimum are so large, that it is impossible to decide whether the form factor changes sign in the third diffraction minimum. This density corresponds to a PWBA form factor without a sign change at that point. The 39K(48Ca) data show a preference for no sign change (a sign change).
3) Assuming a sign change of F(q) in the third diffraction minimum.
4) The 48Ca/40Ca cross-section ratios (Fr68) were normalized using the 40Ca data from ref. Si73a.

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TABLE V. Magnetization-Density-Distribution Parameters

Nucleus	μ [n.m.]	$\langle r^2\rangle_M^{1/2}$ [fm]	a_o [fm]	R	R_{SPM}	q-range [fm^{-1}]	Comparison Nucleus	Ref.	Remarks
n	-1.913								†,1
1H	2.793	0.810(29)				0.99-1.33	abs	Fr66	†,a,2
		0.87				0.66-2.42	abs	Ga72	a,3
		0.85(3)				0.33-1.42	abs	Th72	a,4
		0.86(2)				0.36-1.45	abs	Bo74	a,5
2H	0.857	2.1(1)				0.8 -1.45	abs	Bu66	†,a,6
3H	2.979	1.70(5)				1.0 -2.83	abs	Co65	a,7
3He	-2.128	1.74(10)				1.0 -2.83	abs	Co65	†,a,7
		1.94(19)				0.561	abs	Ch69	a,7
		1.95(11)				1.4 -3.54	1H(Ja66)	MC70	b,8
6Li	0.822	3.42(6)	2.16(4)	0.53(3)	0.438	0.85-1.39	1H(Vr64)	Ra66	†,a,d,9
		2.81	1.78	0.10(3)	0.438	0.85-1.39	1H(Vr64)	Ra66	a,d,10
7Li	3.256	2.69(13)	1.70(8)	0.09(4)	0.117	0.70-1.97	1H(Vr64)	Ra66	†,a
		2.72	1.72	0.08(4)	0.117	0.70-1.97	1H(Vr64)	Ra66	a,10
		3.00(5)	1.90(3)	0	0.117	0.25-0.90	abs	Ni71	a
9Be	-1.178	2.53	1.60	-0.25(2)	-0.200	0.44-0.68	1H(Vr64)	Va65	†,a,11
		2.64(16)	1.67(10)	-0.38(7)	-0.200	0.71-2.27	1H(Vr64)	Ra66	a
		2.53	1.60	-0.30(6)	-0.200	0.71-2.27	1H(Vr64)	Ra66	a,11
		2.78	1.76	-0.93(12)	-0.200	0.35-0.91	abs	La73b	c,12
		2.85(4)	1.80(3)	-0.60(5)	-0.200	0.35-2.27	abs	La73b	c,13
10B	1.801	2.45	1.55	0.69(5)	0.438	0.51-0.68	1H(Vr64)	Va65	†,a,d,11
		2.25(32)	1.42(20)	0.32(5)	0.438	0.71-1.98	1H(Vr64)	Ra66	a,d
		2.45	1.55	0.60(7)	0.438	0.71-1.98	1H(Vr64)	Ra66	a,d,11
11B	2.689	2.37	1.50	0.18(8)	0.117	0.51-0.68	1H(Vr64)	Va65	†,a
		2.42(9)	1.53(6)	0.21(5)	0.117	0.71-2.28	1H(Vr64)	Ra66	a
		2.45	1.55	0.20(5)	0.117	0.71-2.28	1H(Vr64)	Ra66	a,11
14N	0.404	2.55(32)	1.61(20)	2.48(9)	3.36	1.00-1.80	1H(Vr64)	Ra66	†,a,d
27Al	3.641	3.19(11)	1.71(6)	0.251	0.251	0.35-0.96	abs	La73a	†,c
45Sc	4.756	4.05(19)	1.91(9)	0.357	0.357	0.41-0.86	abs	Vr73	c
		4.50(19)	2.12(9)	0.667	0.357	0.41-0.86	abs	Vr73	c,14
51V	5.149	3.69(15)	1.74(7)	0.357	0.357	0.41-0.86	abs	Vr73	†,c
		4.03(17)	1.90(8)	0.667	0.357	0.41-0.86	abs	Vr73	c,14
55Mn	3.444	3.86(21)	1.82(10)	0.357	0.357	0.41-0.86	abs	Vr73	c
		4.18(74)	1.97(35)	0.667	0.357	0.41-0.86	abs	Vr73	c,14
59Co	4.62	3.84(15)	1.81(7)	0.357	0.357	0.41-0.86	abs	Vr73	c
		4.26(17)	2.01(8)	0.667	0.357	0.41-0.86	abs	Vr73	c,14

† Additional information, not tabulated, can be found in the following references:

n : Vr64, Du65, Ch66a, Du66, Gr66a, Gr66b, Hu66a, Al68, Bu68, Bu69, El69, Ba72, Ha73a.
1H : Dr62, Be63, Ch63, Du63, Du65, Al66, Ba66, Ch66a, Ch66b, Ja66, Al67, Ba67a, Be67a, Go67, Be68, Co68, Ba70, Go70, Li70a, Be71a, Ha71, Pr71, Bo73b, Ki73, Si73e, Th74.
2H : Be64a, Go64, Gr66a, Ra67, Al68, El69, Ga71, Ga72, Ra73, Sk73.
3He: Be72a.
6Li: Pe62, Go63b.
7Li: Pe62, Go63b.
9Be: Go63b.
10B : Go63b, Go65.
11B : Go63b, Go65.
13C : He70a.
14N : Go63b, Da70.
15N : Da70.
19F : Go63b.
27Al: Go63b, St67, Li70b, Do73.
31P : Go63b, Si71.
39K : Go63b.
51V : Pe73.
209Bi: Li70b.

a) Analysis performed using the Plane Wave Born Approximation.
b) Analysis performed using the Modified Born Approximation.
c) Analysis performed using the Distorted Wave Born Approximation.
d) For odd-odd nuclei the column R_{SPM} gives the value calculated in extreme j-j coupling.

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TABLE V. Magnetization-Density-Distribution Parameters

Remarks

1) From elastic and inelastic electron-deuteron experiments the neutron's magnetic moment distribution seems to be approximately similar to that of the proton. Further information on the neutron magnetic form factor can be obtained from the list of additional references.
2) Value derived from experiments in which the recoil proton has been observed; model-independent evaluation.
3) Value derived by Ganichot et al (Ga72) from an analysis with a one pole model of all available data below $q^2 = 6\ fm^{-2}$ (Dr62, Du65, Gr66b, Ja66).
4) Model-independent value derived by Theissen (Th72) from an analysis of all available data below $q^2 = 2\ fm^{-2}$ (Dr62, Du65, Fr66, Th72).
5) Value derived by Borkowski et al (Bo74) from an analysis using a sum of single poles model for the electric and magnetic proton form factors.
6) See also ref. Ho67, discussion 38.
7) Model-independent analysis.
8) Analysis using a magnetization distribution as defined in remark 8 of table I (without modification), yielding a = 0.456(29) fm, b = 0.654(24) fm and c = 0.82(5) fm.
9) The error quoted for a_o is for a fixed value of R. A large range of (a_o,R)-values yield adequate fits to the data.
10) The data were analyzed using a value for a_o derived from charge scattering experiments (ref. Be65).
11) The data were analyzed using a value for a_o derived from charge scattering experiments (ref. Me59).
12) The data were analyzed using a value for a_o derived from charge scattering experiments (ref. Ja72).
13) Combined analysis of low- and high-energy data (Va65, Ra66, La73b).
14) The data were analyzed using a value of R as predicted by the single particle model with a Dirac proton in the $1f_{7/2}$-shell.

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