Electron scattering from proton-rich nuclei

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Outline

- Introduction
- Basic theory of Electron Scattering
- Results and Discussions
- Summary and Outlook

Introduction

- **Electron scattering is an electromagnetic probe which can provide the most accurate nuclear structure information.**
  - **well-known electromagnetic interaction mechanism**
  - **electron is very light compared to nucleon**

1950-1960: Charge densities of many stable nuclei were measured by Coulomb scattering. (Hofstadter 1961 Nobel Prize)
1970-1990: Magnetic current densities of several nuclei were measured by magnetic scattering.

- In 21st century new structure of radioactive nuclei, such as proton halo, neutron halo have been found.
- The SCRIT electron scattering facility has been constructed at RIKEN, electron scattering experiment with short-lived nuclei is availaable (132Xe). Other facilities, such as ELISe in Darmstadt will be available.
- Parity Violating Electron Scattering experiment PREX-I (^{208}Pb Radius EXperiment) has been run in 2010, PREX-II and CREX (^{48}Ca) is done.

Basic theory of Electron Scattering

- Plane Wave Born Approximation
- Eikonal approximation
- Phase shift analysis

Plane Wave Born Approximation

Cross section of elastic electron scattering:

$$\frac{d\sigma}{d\Omega} = \sigma_M f_{rec} [F_L^2(q^2) + (\frac{1}{2} + \tan^2\frac{\theta}{2}) F_T^2(q^2)]$$

Mott cross section $$\sigma_M = \frac{(Z\alpha)^2 \cos^2\frac{\theta}{2}}{4E_i^2 \sin^4\frac{\theta}{2}}$$

Recoil factor $$f_{rec} = (1 + \frac{2E_i \sin^2\frac{\theta}{2}}{Mc^2})^{-1}$$

Longitudinal form factor

$$F_L^2 = \sum_{\lambda=0} |F_\lambda^C(q)|^2$$

$$F_\lambda^C(q) = \int_0^\infty \rho_\lambda(r) j_\lambda(qr) r^2 dr$$

Transverse form factor

$$F_T^2 = \sum_{\lambda=1} |F_\lambda^M(q)|^2$$

$$F_\lambda^M(q) = \int_0^\infty J_{\lambda\lambda}(r) j_\lambda(qr) r^2 dr$$

Elastic Coulomb electron scattering

In PWBA, the charge form factor is the Fourier transform of charge density

$$F(q) = \int_0^\infty \rho(r) j_0(qr) r^2 dr \qquad \textbf{(spherical nuclei)}$$

- For small momentum transfer region $q \to 0$

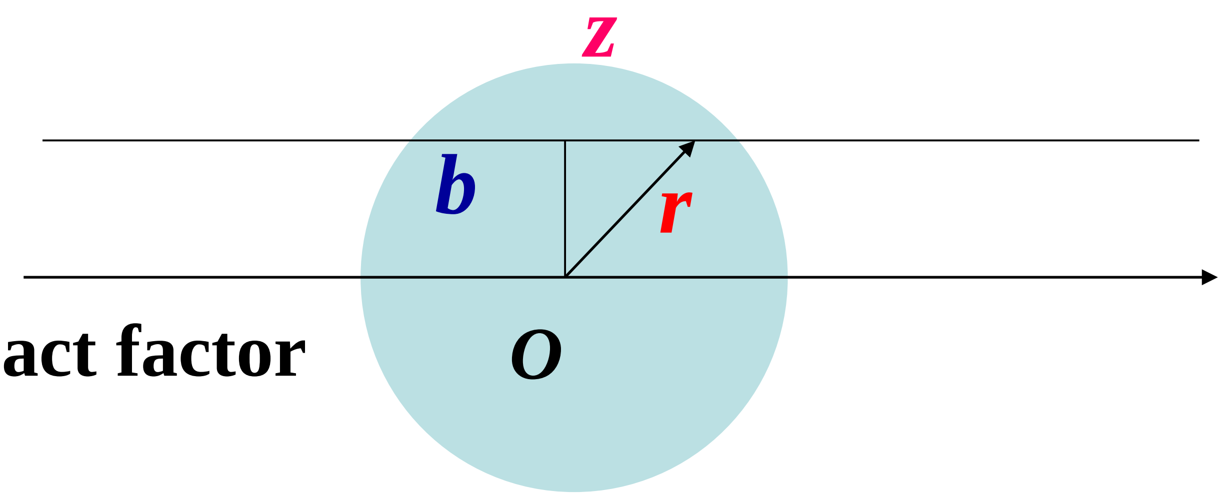
$$F(q) \simeq 1 - \frac{1}{6}\left\langle r^2 \right\rangle q^2 + \dots$$

- The detailed charge density can be derived from the form factor in large q region.

Eikonal approximation

Glauber, *Lectures in Theoretical Physics Vol.1* (1959) **(non-relativistic)**
Baker, *Phys. Rev. 134*, B240 (1964) **(relativistic)**

In spirit, Eikonal approximation is a high energy small angle approximation.



***b*: Impact factor**

Main formulas of Eikonal approximation

$$(\alpha\cdot\vec{p}+\beta m+V_C)\Psi=E\Psi$$

$$\sigma(\theta)=\cos^2(\theta/2)\,|\,I_1(q)+I_2(q)\,|^2$$

$$I_1(q)=-ik\int_0^R J_0(qb)[e^{2i\chi(b)}-1]bdb$$

$$I_2(q)=-ik\int_R^\infty J_0(qb)[e^{2i\chi(b)}-1]bdb.$$

Phase shift:

$$\chi(b)=-\frac{1}{2}\int_{-\infty}^{\infty}V(r)dz,\qquad r=\sqrt{b^2+z^2}$$

Phase shift analysis

Wave function of electrons:

$$\Psi(\vec{r}) = \frac{1}{r}\begin{bmatrix} P(r)\Omega_{\kappa,m}(\theta,\phi) \\ iQ(r)\Omega_{-\kappa,m}(\theta,\phi) \end{bmatrix}$$

Radial equations:

$$\frac{dP}{dr} = -\frac{\kappa}{r}P(r) + (E - V + 2m)Q(r)$$

$$\frac{dQ}{dr} = -(E - V)P(r) + \frac{\kappa}{r}P(r)$$

The asymptotical behavior of *P(r)*

$$P(r) \xrightarrow{r\to\infty} \sin(kr - l\pi/2 + \delta_\kappa)$$

Direct scattering amplitude:

$$f(\theta) = \frac{1}{2ik}\sum_{l=0}[(l+1)(e^{2i\delta_{\kappa=-l-1}} - 1) + l(e^{2i\delta_{\kappa=l}} - 1)]P_l(\cos\theta)$$

Spin-flip scattering amplitude:

$$g(\theta) = \frac{1}{2ik}\sum_{l=0}[e^{2i\delta_{\kappa=l}} - e^{2i\delta_{\kappa=-l-1}}]P_l^1(\cos\theta)$$

Differential cross section:

$$\frac{d\sigma}{d\Omega} = |f(\theta)|^2 + |g(\theta)|^2$$

Results and Discussions of our group

- **Elastic Coulomb electron scattering**

  this talk.

- **Elastic magnetic electron scattering**

  T. K . Dong's talk (tomorrow)

- **Parity violating electron scattering**

  this talk

Elastic Coulomb electron scattering

I am interested in electron sacttering in 1996

when I studied proton halo in light nuclei

(^{26}P, ^{27}S: proton-rich nuclei)

We predicted there are proton halos in the two nuclei.

- **We mentioned in the article (Ren et al. PRC, 1996) that electron-scattering is a good way to test proton halo as it is a charged halo.**

Prediction : proton halos in ^{26}P,^{27}S

D COMMUNICATIONS

PHYSICAL REVIEW C VOLUME 53, NUMBER 2 FEBRUARY 1996

One-proton halo in ^{26}P and two-proton halo in ^{27}S

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(Received 7 September 1995)

Proton-drip-line nuclei ^{26}P and ^{27}S are studied in the nonlinear relativistic mean-field theory. Calculations show that the mean-square radius of protons in the $2s_{1/2}$ state is approximately 18–20 fm^2 which is abnormally large as compared with the mean-square radii of proton, neutron, and matter distributions, giving a strong evidence for proton halos in ^{26}P and ^{27}S. This indicates that the size of proton halos is as large as that of neutron halos although there exists the Coulomb barrier in proton-drip-line nuclei.

PACS number(s): 21.10.Gv, 21.60.Jz, 21.10.Dr, 27.30.+t.

25 July 1996

PHYSICS LETTERS B

ELSEVIER

Physics Letters B 381 (1996) 391–396

Proton halos in the $1s0d$ shell

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Received 10 April 1996; revised manuscript received 15 May 1996
Editor: C. Mahaux

Abstract

The shell-model properties of proton halo states in proton-rich $1s0d$ shell nuclei are investigated. The most interesting cases appear to be those in ^{26,27}P and ^{27}S. The parallel-momentum distributions of core fragments from proton stripping reactions

as a function of proton number. The difference $\Delta_{np} = S_n - S_p$, is also given. It clear that ^{26}P is potentially the most interesting loosely bound case, as has been pointed out recently on the basis of relativistic mean-field calculations [19], and it is known [20] to be

the one-proton separation energy is about the same in both cases. As pointed out in Ref. [19], ^{27}S also has the property of a relatively loosely bound di-proton system. The two-proton separation energies for Z =

It clear that ^{26}P is potentially the most interesting loosely bound case, as has been pointed out ...[19]

As pointed out in reference [19], ^{27}S also has the property of … loosely bound diproton system.

[19] Z. Ren, B. Chen, Z. Ma and G. Xu, Phys. Rev. C 53 (1996) R572.

Expt. confirmation: proton halo of ^{26,27,28}P

VOLUME 81, NUMBER 23 PHYSICAL REVIEW LETTERS 7 DECEMBER 1998

Spectroscopy of Radioactive Beams from Single-Nucleon Knockout Reactions: Application to the *sd* Shell Nuclei ^{25}Al and ^{26,27,28}P

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(Received 10 August 1998)

Measurements of deexcitation γ rays in coincidence with the momentum distribution of the projectile residues produced in reactions of the type ^{9}Be(^{28}P, ^{27}Si + γ)X at energies around 65 MeV/u are used to study single-nucleon stripping to individual states. The cross sections are compared with calculations based on an eikonal model description of the reaction and the shell model. The measurements indicate that the halo character of the ground state and other detailed spectroscopic information can be derived using knockout reactions in inverse kinematics. [S0031-9007(98)07825-9]

PACS numbers: 25.60.Gc, 21.10.Jx, 25.70.Mn, 27.30.+t

THE EUROPEAN PHYSICAL JOURNAL A

Expt. : proton halo ^{27}P

Eur. Phys. J. A **12**, 335–339 (2001)

Evidence for a proton halo in ^{27}P through measurements of reaction cross-sections at intermediate energies

D.Q. Fang[1,a], W.Q. Shen[1,3], J. Feng[1], X.Z. Cai[1], H.Y. Zhang[1], Y.G. Ma[1], C. Zhong[1], Z.Y. Zhu[1], W.Z. Jiang[1], W.L. Zhan[2], Z.Y. Guo[2], G.Q. Xiao[2], J.S. Wang[2], J.Q. Wang[2], J.X. Li[2], M. Wang[2], J.F. Wang[2], Z.J. Ning[2], Q.J. Wang[2], and Z.Q. Chen[2]

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Up to now, the heaviest well-established halo nucleus is ^{19}C [6–10]. However, the proton halo in ^{26,27,28}P and ^{27,28,29}S has been proposed within the framework of shell model and relativistic mean-field (RMF) calculations [26–29].

Predictions on proton halos in ^{26,27,28}Pand ^{27,28,29}S [26-29]。

26. B.A. Brown, P.G. Hansen, Phys. Lett. B **381**, 391 (1996).
27. Z.Z. Ren, B.Q. Chen, Z.Y. Ma, G.O. Xu, Phys. Rev. C **53**, R572 (1996).
28. B.Q. Chen, Z.Y. Ma, F. Grummer, S. Krewald, J. Phys. G **24**, 97 (1998).
29. Z.Z. Ren, W. Mittig, F. Sarazin, Nucl. Phys. A **652**, 250 (1999).

Expt.: proton halo in ^{27,28}P (PRC 2004)

PHYSICAL REVIEW C **69**, 034326 (2004)

Evidence for enhancement of the total reaction cross sections for ^{27,28}P with a ^{28}Si target and examination of possibly relevant mechanisms

Z. H. Liu, M. Ruan, Y. L. Zhao, H. Q. Zhang, F. Yang, Z. Y. Ma, C. J. Lin, B. Q. Chen, and Y. W. Wu
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W. L. Zhan, Z. Y. Guo, G. Q. Xiao, H. S. Xu, Z. Y. Sun, J. X. Li, and Z. J. Chen
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(Received 26 June 2003; published 22 March 2004)

I. INTRODUCTION

Recently, Navin *et al.* [1] confirmed the important role of the $\pi s_{1/2}$ orbital in the predicted halo structure [2–4] of the neutron-deficient phosphorus isotopes ^{26,27,28}P by measurements of deexcitation γ ray in coincidence with the momentum distribution of the projectile residues.

Navin et al. [1] confirmd …predicted halo structure [2-4] of…$^{26\text{-}28}$P
实验证实[1]理论预言的^{26,27,28}P有质子晕[2-4]。

[1] A. Navin *et al.*, Phys. Rev. Lett. **81**, 5089 (1998).
[2] B. A. Brown and P. G. Hansen, Phys. Lett. B **381**, 391 (1996).
[3] Z. Z. Ren, B. Q. Chen, Z. Y. Ma, and G. O. Xu, Phys. Rev. C **53**, 572 (1996).

Calculate elastic electron scattering on proton-rich nuclei, to confirm proton halos in $^{27,28}S$ (future)

PHYSICAL REVIEW C **70**, 034303 (2004)

Elastic electron scattering on exotic light proton-rich nuclei

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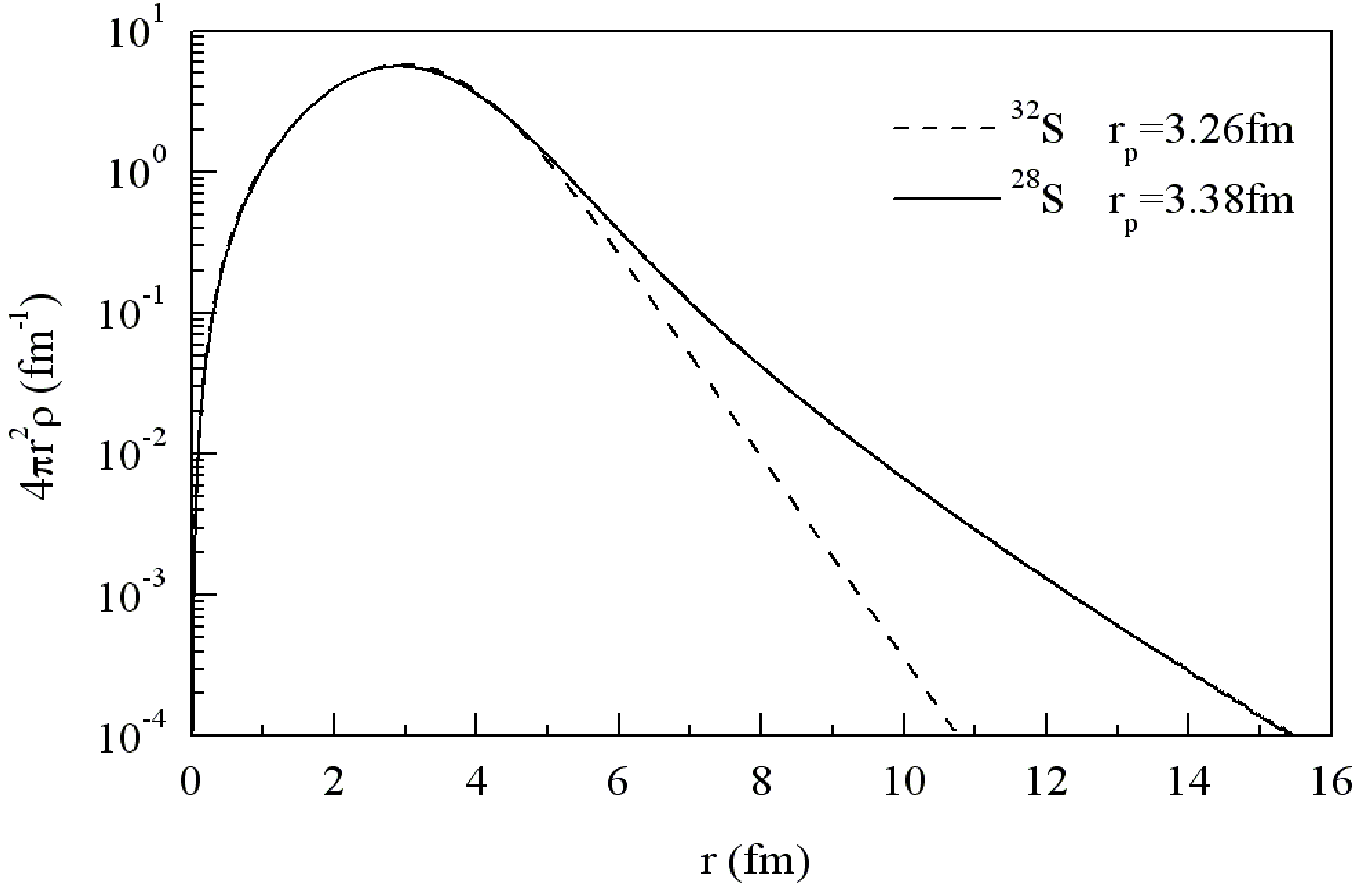
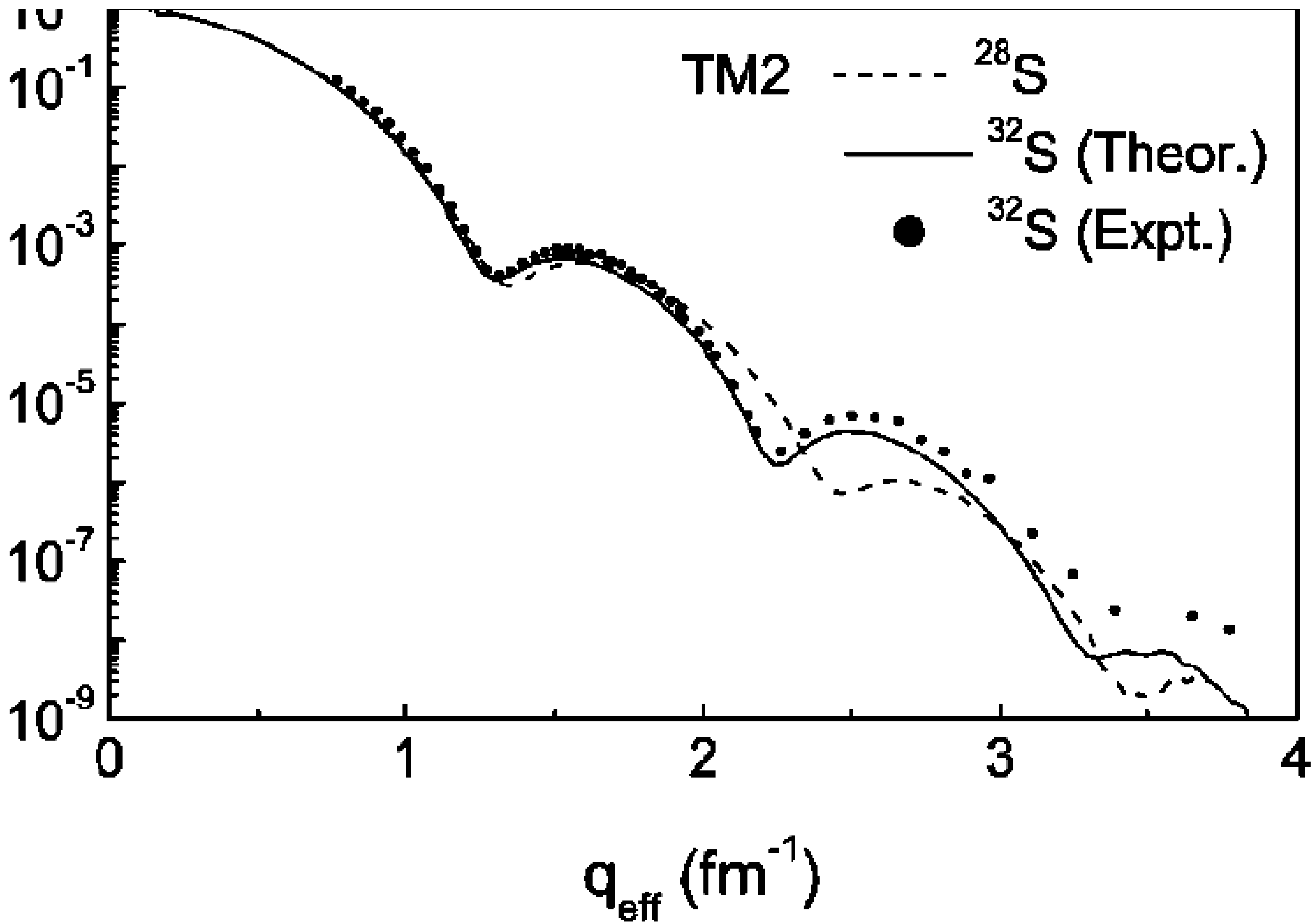
(Received 29 April 2004; published 10 September 2004)

Recent experiments show that there may exist proton halos in exotic light proton-rich nuclei. We investigate the effect of an extended proton density distribution on the cross sections and form factors of elastic electron scattering from the exotic proton drip-line nuclei ^{28}S and ^{12}O. With charge density distributions from the self-consistent relativistic mean field model, we calculate the cross sections and form factors for elastic electron scattering in the eikonal approximation. The numerical results are compared with the available data of the stable nuclei ^{32}S and ^{16}O. The results show that the form factors and cross sections for elastic electron scattering at intermediate-momentum transfers are very sensitive to the alterations of the charge density distributions of the last protons in exotic nuclei ^{28}S and ^{12}O. This is an interesting combination of the reliable relativistic mean field model with the model of electron-nucleus scattering and it can be useful for future experiments.

Charge density distributions of ^{28}S (halo)， ^{32}S



Form factors of ^{28}S, ^{32}S, near second minimum



Elastic scattering with isotonic chain (I1)

PHYSICAL REVIEW C **73**, 014610 (2006)

Charge density distributions and charge form factors of the $N = 82$ and $N = 126$ isotonic nuclei

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Charge form factors for $N = 82$ and $N = 126$ isotonic nuclei are calculated with the relativistic eikonal approximation, in which the charge density distributions are from the relativistic mean-field theory. The variations of charge form factors with proton number are discussed in detail. It is found that the most sensitive parts of the charge form factors are those around the minimums and maximums. For an increasing proton number, the charge form factors near the extrema have an upward shift. As the protons increase and occupy a new shell, the minimums and maximums of the charge form factors could also have a significant inward shift. The results can be useful for the study of behaviors of valence-proton wave functions for such nuclei as can be considered as a core plus proton(s), and thus the proton-halo phenomenon. In addition, the results can also be useful for future electron-unstable nucleus scattering experiments and provide tests of the reliability of the relativistic mean-field theory for the unstable nuclei.

TABLE I. The RMF results with the TM1 parameter set and the corresponding experimental values for the $N = 82$ isotonic nuclei.

Nuclide	Z	E/A (MeV)	E/A(expt) (MeV)	R (fm)	R(expt) (fm)
^{132}Sn	50	8.343	8.355	4.739	
^{134}Te	52	8.389	8.383	4.783	
^{136}Xe	54	8.416	8.396	4.824	4.800
^{138}Ba	56	8.434	8.393	4.862	4.839
^{140}Ce	58	8.434	8.376	4.899	4.880
^{144}Sm	62	8.338	8.303	4.965	4.976
^{146}Gd	64	8.270	8.250	4.996	
^{148}Dy	66	8.164	8.181	5.037	

where $Q^2 = 18.29\,\mathrm{fm}^2 = 0.71\,\mathrm{GeV}^2(\hbar c = 0.197\,\mathrm{GeV\ fm} = 1)$. The corresponding rms charge radius of the proton is $r_p = 0.81$ fm.

We first produce the charge density distributions by using the RMF model. Since we are now dealing with medium-heavy and heavy nuclei, we use the TM1 force parameter set [60],

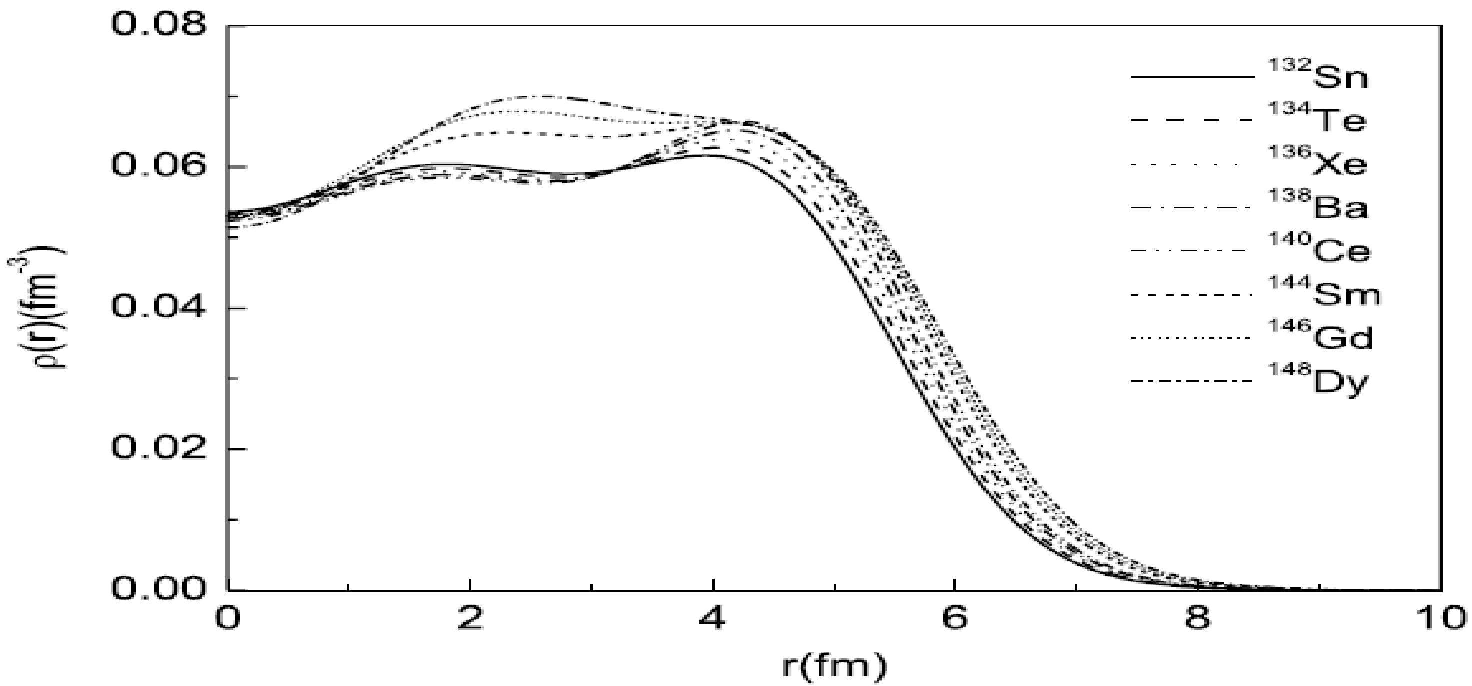


FIG. 1. Variation of charge density distributions for the $N = 82$ isotonic nuclei calculated with the RMF model.

the charge distributions for these nuclei, whereas for ^{144}Sm, ^{146}Gd, and ^{148}Dy the features of the charge distributions are quite different. There is only one peak in the charge distributions. The depression near $r = 3.0$ fm for ^{132}Sn, ^{134}Te, ^{136}Xe, ^{138}Ba, and ^{140}Ce is replaced with this peak. We consider that this peak results mainly from the occupation of the $2d$ shell by the additional protons (relative to ^{140}Ce) as the

Form factors of isotones N=82 (I1)

PHYSICAL REVIEW C **73**, 014610 (2006)

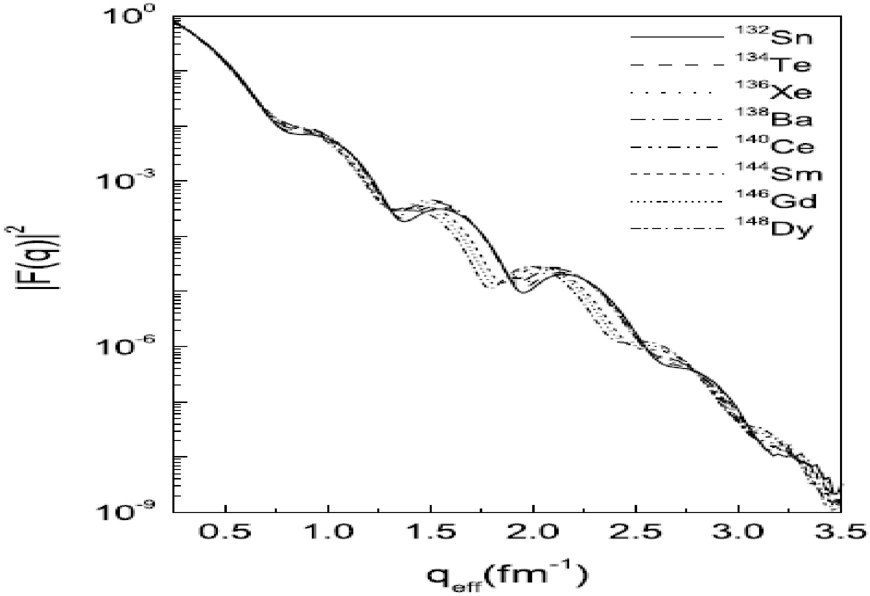


FIG. 3. Variation of the charge form factors with proton number for the $N = 82$ isotonic nuclei ($Z = 50$–66).

the minimums and maximums. This shows that the shapes of the charge density distributions of these nuclei are not particularly different except near the surface. This agrees with the charge density distributions shown in Fig. 1. The reason is that, although the proton numbers of these nuclei are not the same, their last protons are all mainly in the same shell, i.e., the $1g$ shell. This indicates that, for isotonic nuclei, the shape of the charge density distribution will not be much disturbed when more protons are added to the same shell.

Sensitive near the minimum around 1.75fm^{-1} due to proton occupations

CHARGE DENSITY DISTRIBUTIONS AND CHARGE . . .

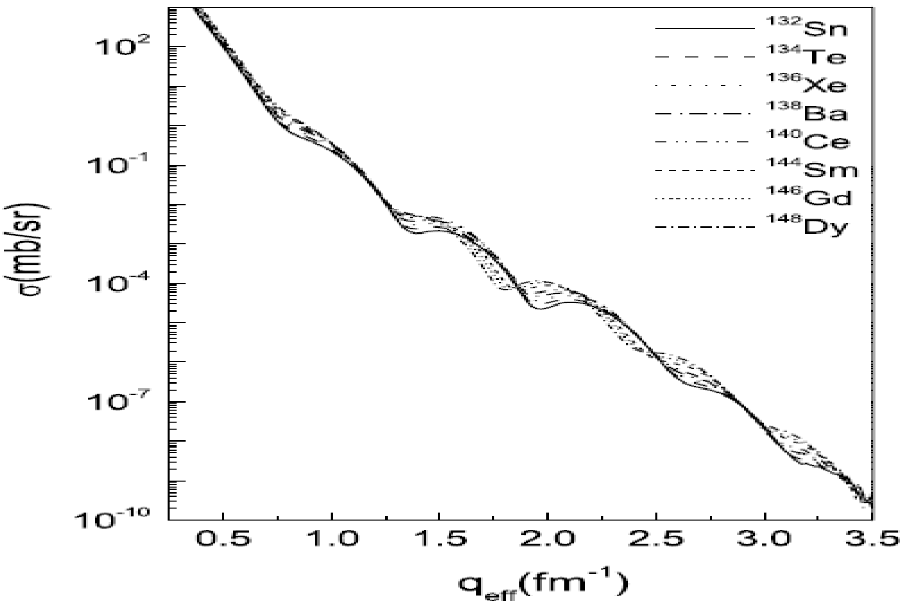


FIG. 4. Variation of the differential cross sections with proton number for the $N = 82$ isotonic nuclei ($Z = 50$–66).

the $2d$ shell is revealed by the inward and upward shift of the charge form factors. The large inward and upward shifts show that the charge form factor is very sensitive to the occupation of a new shell by protons. The largest shifts occur within the range of momentum transfer $1.25\ \mathrm{fm}^{-1} \leqslant q_{\mathrm{eff}} \leqslant 2.75\ \mathrm{fm}^{-1}$.

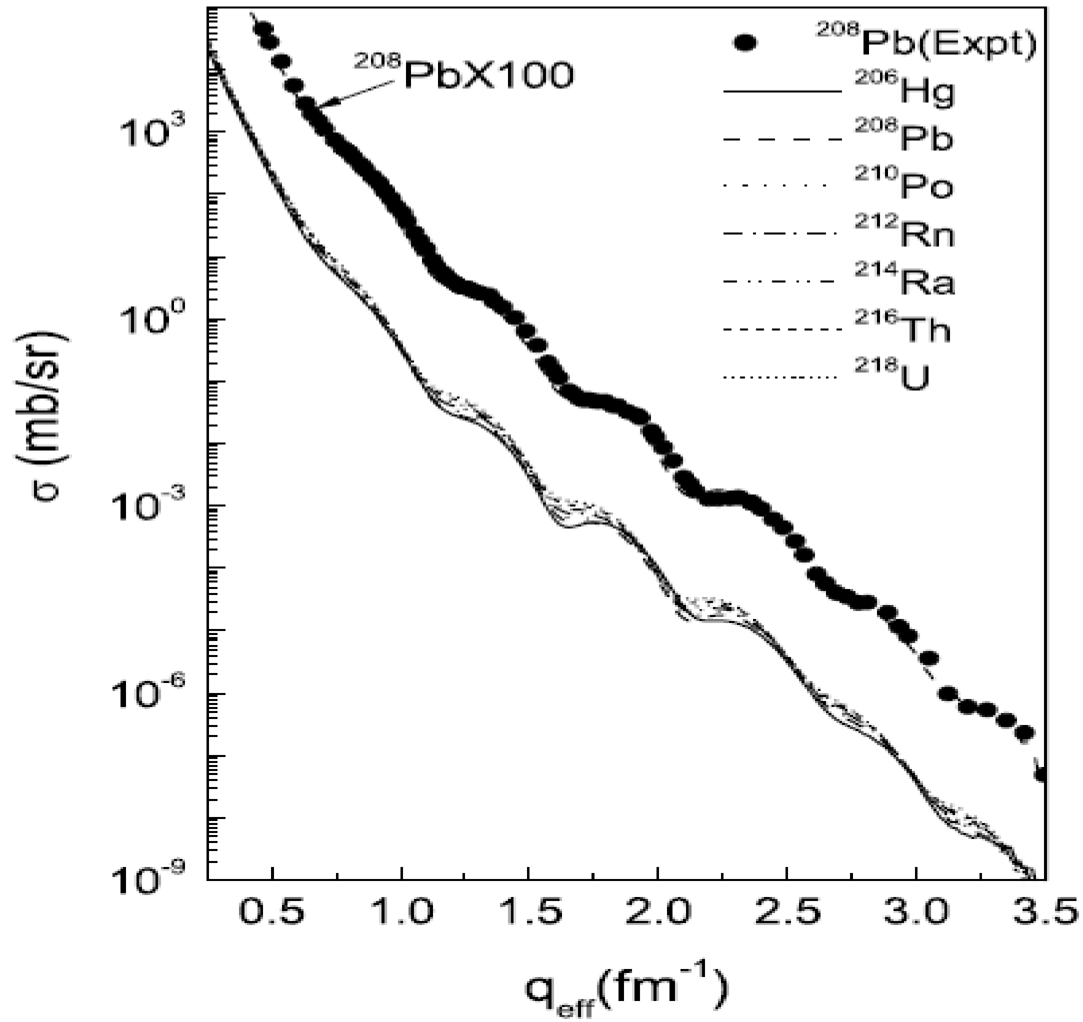


FIG. 6. Variation of the differential cross sections with proton number for the $N = 126$ isotonic nuclei ($Z = 80$–92).

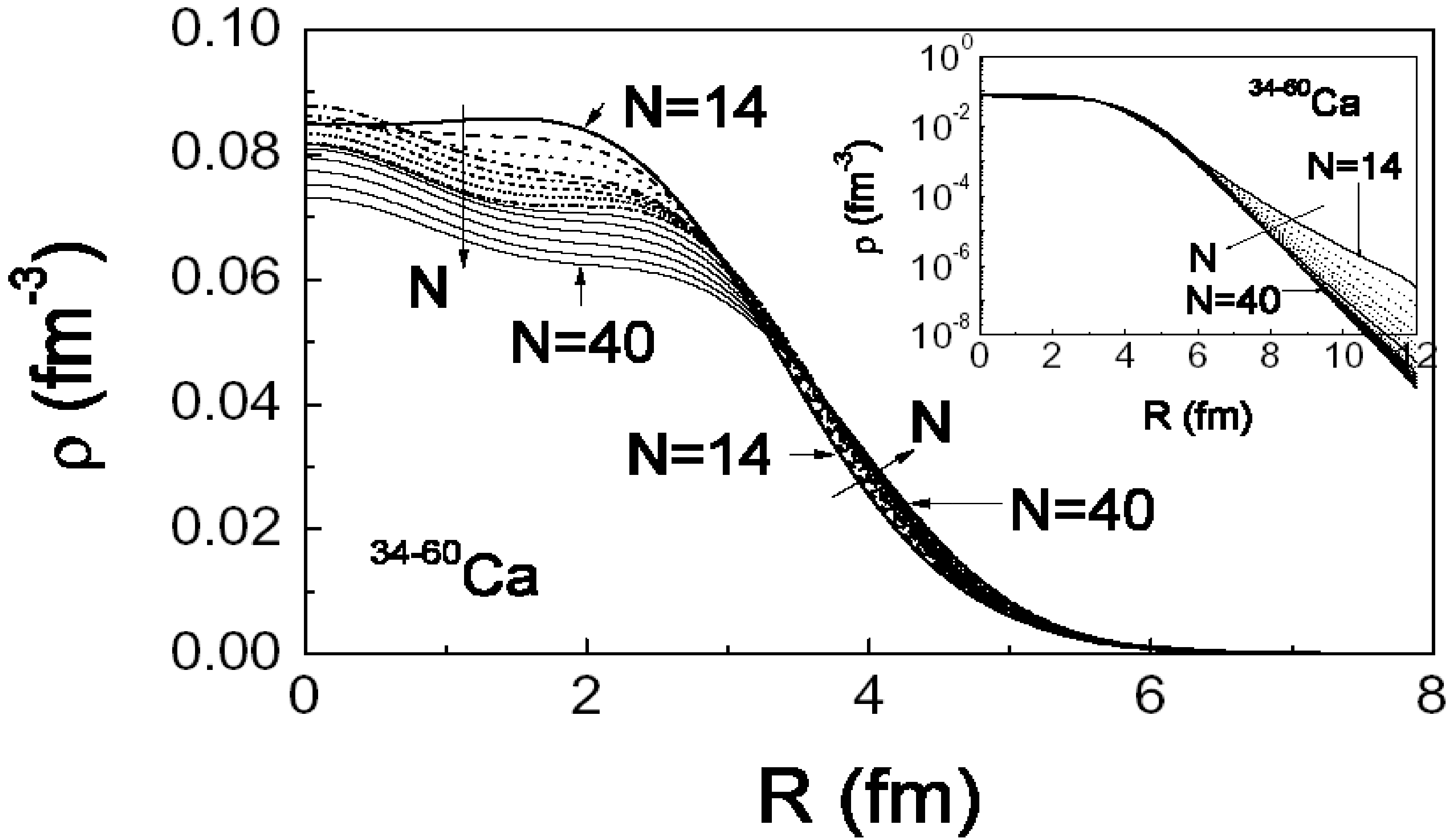
Elastic scattering is sensitive to the occupation of protons to a new shell (I1)

This indicates that the charge form factors within that range of momentum transfer are the most sensitive to a change in proton number. Thus, when the proton number increases and a new shell is occupied, the change of shape of the charge distribution resulting from the occupation of a new proton shell may be observed through electron scattering. Figure 4 is the differential cross sections for these nuclei. One can find that the variational behaviors of the differential cross sections are the same as those of the form factors, and thus the same results and conclusion can be obtained through the analysis of the cross sections.

Motivations: new phenomena of proton-rich nuclei due to rare studies on proton-rich side

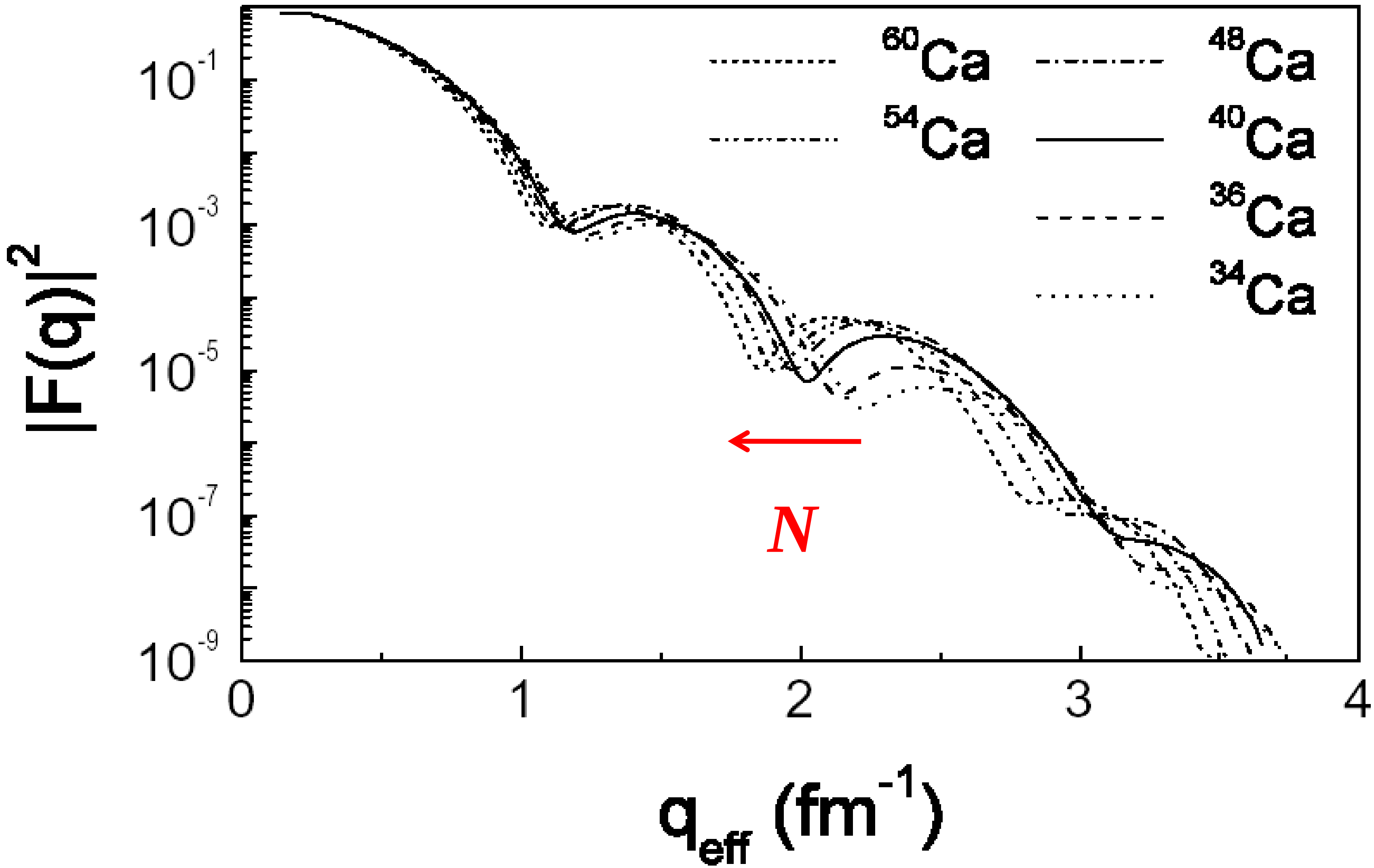
neutrons is zero. Up to now neutron halos have been observed for nuclei such as ^{6,8}He, ^{11}Li, ^{11,14}Be, ^{17}B, and ^{19}C. Neutron halos have been well studied and will be further investigated in big laboratories [1–3,6,17,69]. However, studies on proton halos and proton skins of light proton-rich nuclei are rare compared with those on neutron halos. This means that there are many new phenomena on proton halos that will be explored by both experimental physicists and theoretical physicists. At the moment, studies on proton halos are exploratory, and the existence of proton halos in some light proton-rich nuclei has been established by independent experiments in some big laboratories. For example, both the RMF model and the shell model predict that there are proton halos in the ground state of $^{26-27}$P and ^{27,28}S [23,24,58]. The experiment from Michigan State University clearly shows that there are proton halos in $^{26-27}$P by the measurement of momentum distributions [13].

Charge density distribution of Ca



Z J Wang, Z Z Ren, PRC 71, 054323 (2005)

Form factor of Ca isotopes



Parity violating electron scattering:

For neutron density distribution

Dirac's equation

$$[\alpha \cdot \vec{p} + \beta m + \hat{V}(r)]\Psi = E\Psi$$

$$\hat{V}(r) = V_C(r) + \gamma_5 A(r)$$

Weak potential: $$A(r) = \frac{G_F}{2\sqrt{2}}\rho_W(r)$$

$$\rho_W(r) = (1 - 4\sin^2\theta_W)\rho_p(r) - \rho_n(r) \quad , \sin^2\theta_W = 0.23$$

The weak charge density is mainly determined by the neutron density distributions.

In high energy, the Dirac's equation can be reduced as follows:

$$[\alpha \cdot \vec{p} + \hat{V}_{\pm}(r)]\Psi_{\pm} = \mathrm{E}\Psi_{\pm}$$

$$\hat{V}_{\pm}(r) = V_C(r) \pm A(r)$$

The left- and right-handed electrons will feel different potentials, so the cross section will differ from each other.

Parity violating asymmetry (PVA):

$$A_{LR} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

In PWBA:

$$A_{LR} = \frac{G_F q^2}{4\pi\sqrt{2}\alpha}\left[\frac{F_n(q)}{F_p(q)} + 4\sin^2\theta_W - 1\right]$$

In Eikonal approximation:

Phase shift for left- and right-handed electrons:

$$\chi_\pm(b) = \chi_C(b) \pm \chi_W(b)$$

$$\chi_C(b) = -\frac{1}{2}\int_{-\infty}^{\infty} V_C(r)dz$$

$$\chi_W(b) = -\frac{1}{2}\int_{-\infty}^{\infty} A(r)dz$$

Cross section:

$$\sigma^{\pm}(\theta) = \cos^2(\theta/2)\,|\,I_1(q) + I_2(q) \pm I_W(q)\,|^2$$

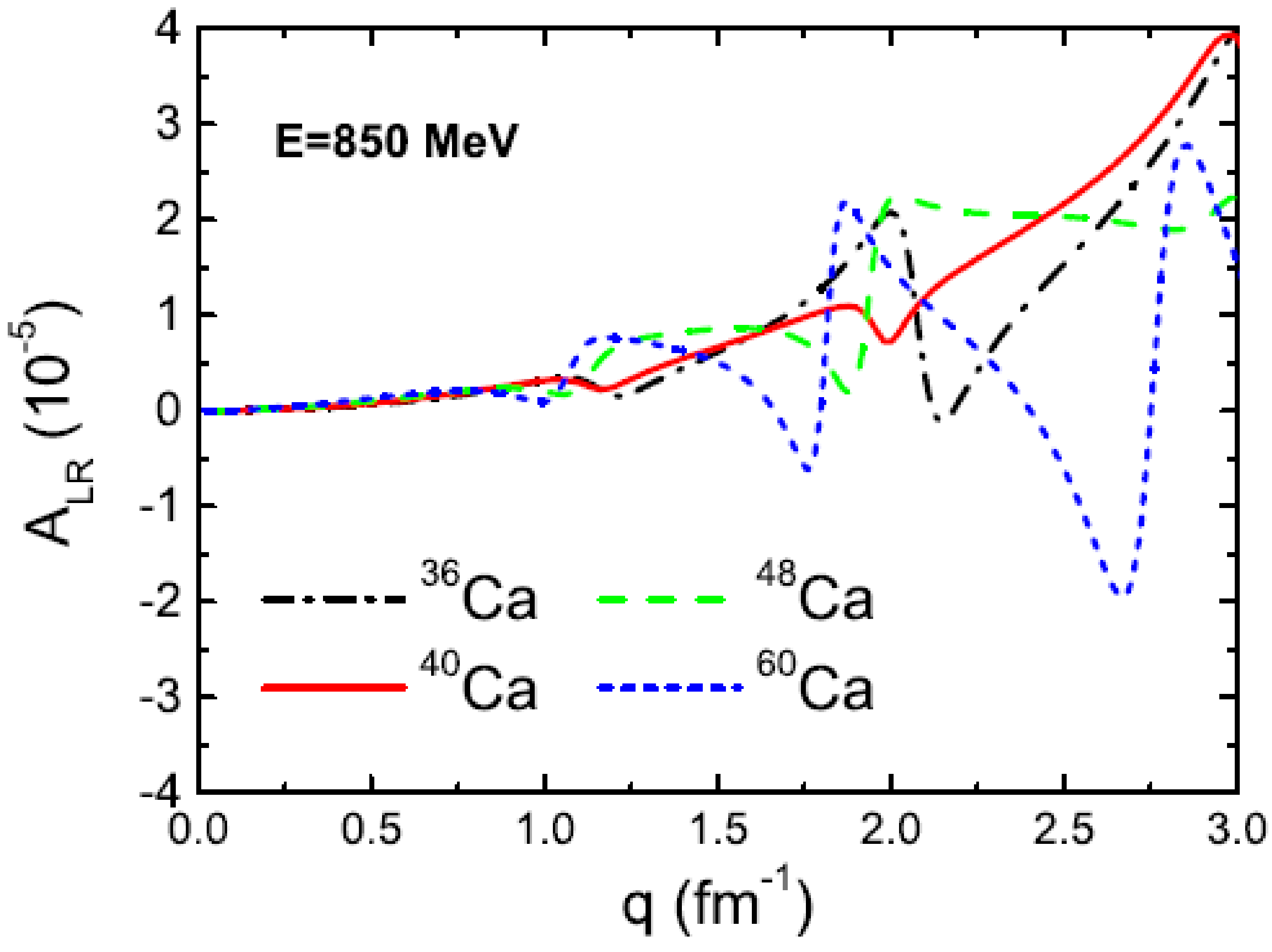
$$I_1(q) = -ik\int_0^R J_0(qb)[e^{2i\chi_C(b)} - 1]bdb$$

$$I_2(q) = -ik\int_R^\infty J_0(qb)[e^{2i\chi_C(b)} - 1]bdb$$

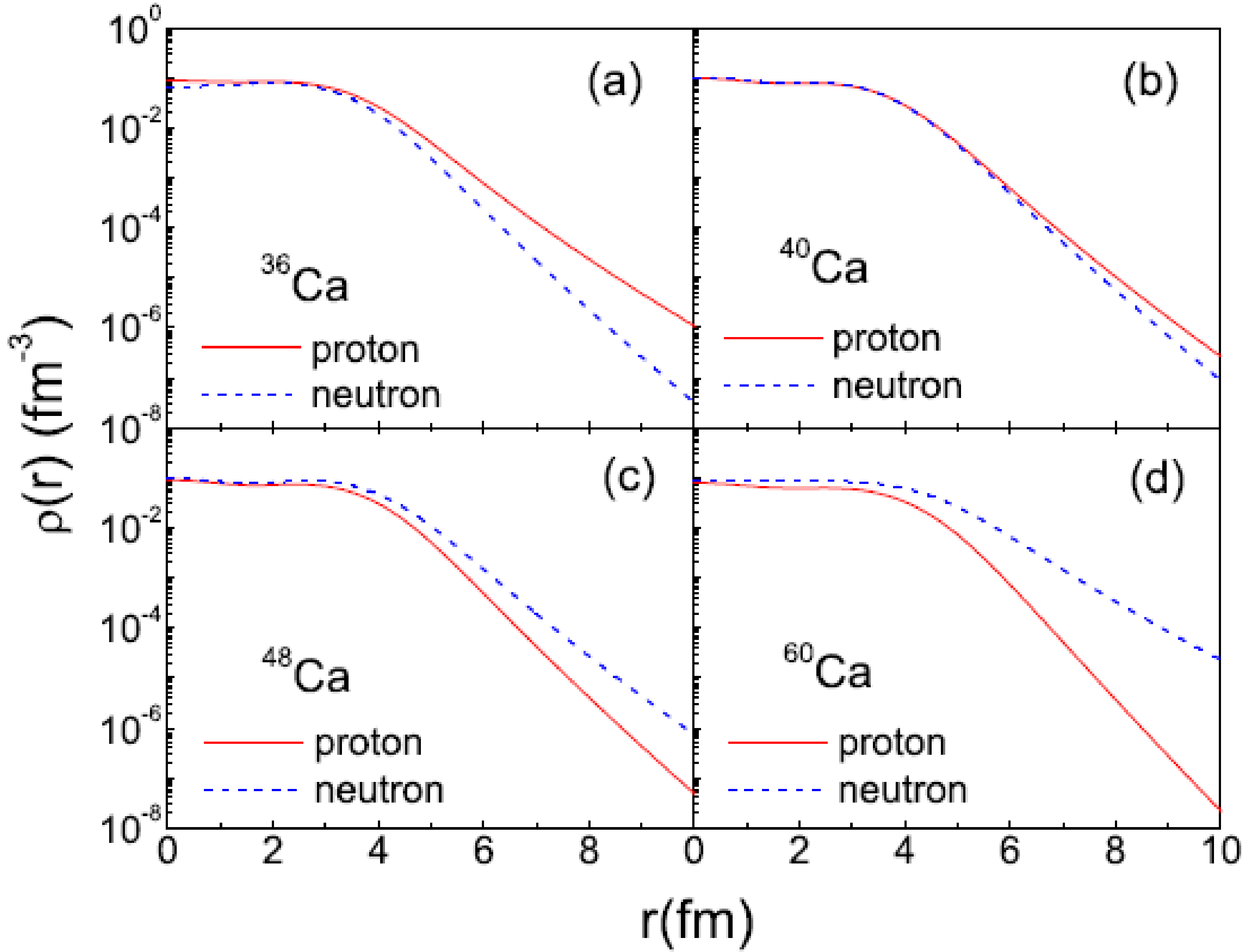
$$I_W(q) = 2k\int_0^R J_0(qb)\chi_W(b)e^{2i\chi_C(b)}bdb$$

The parity violation originates from the interference between the Coulomb and weak amplitudes.

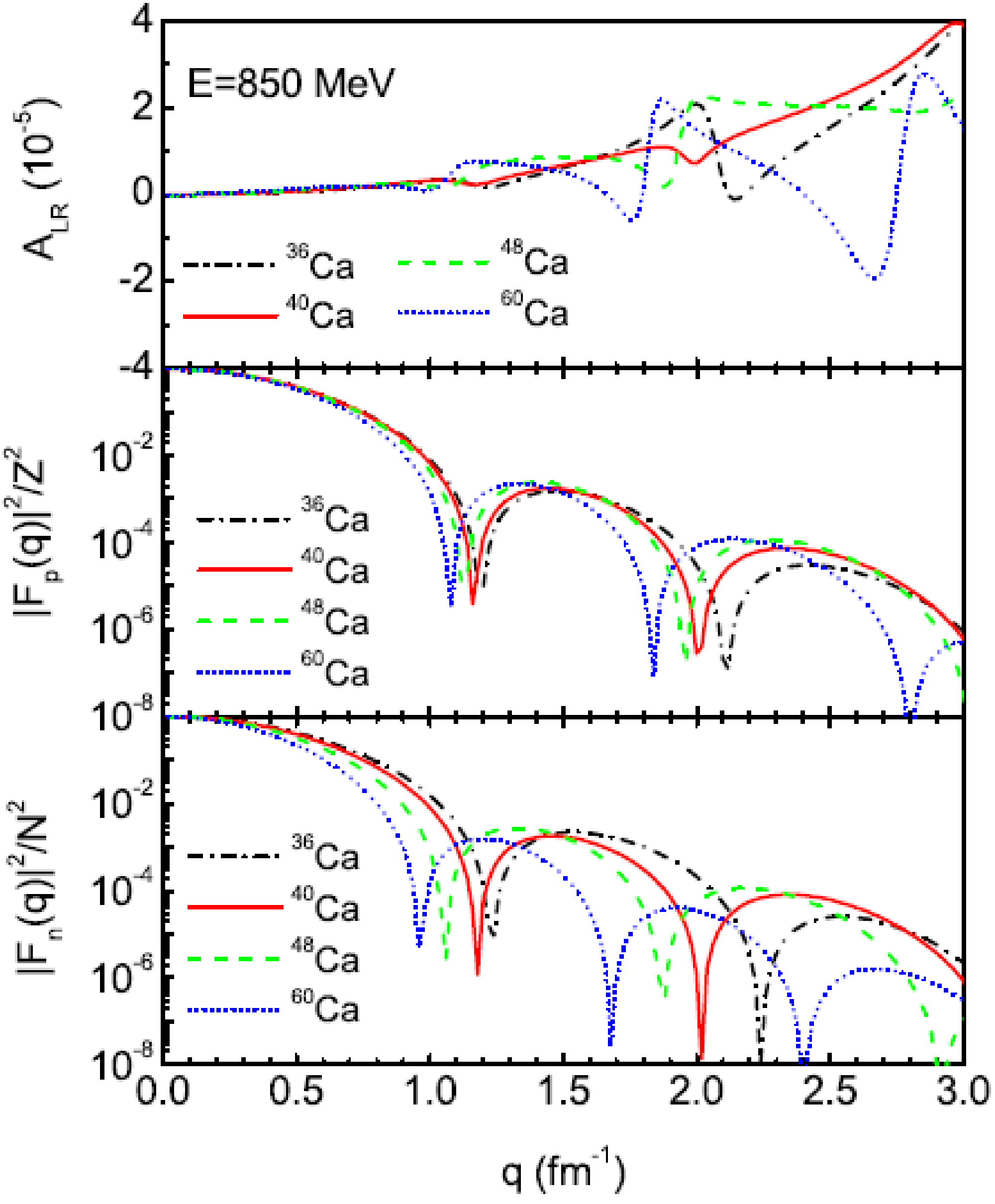
PVA for Ca isotopes



Neutron and proton densities of Ca isotopes



$$A_{LR}(q) \propto \frac{F_n(q)}{F_p(q)}$$



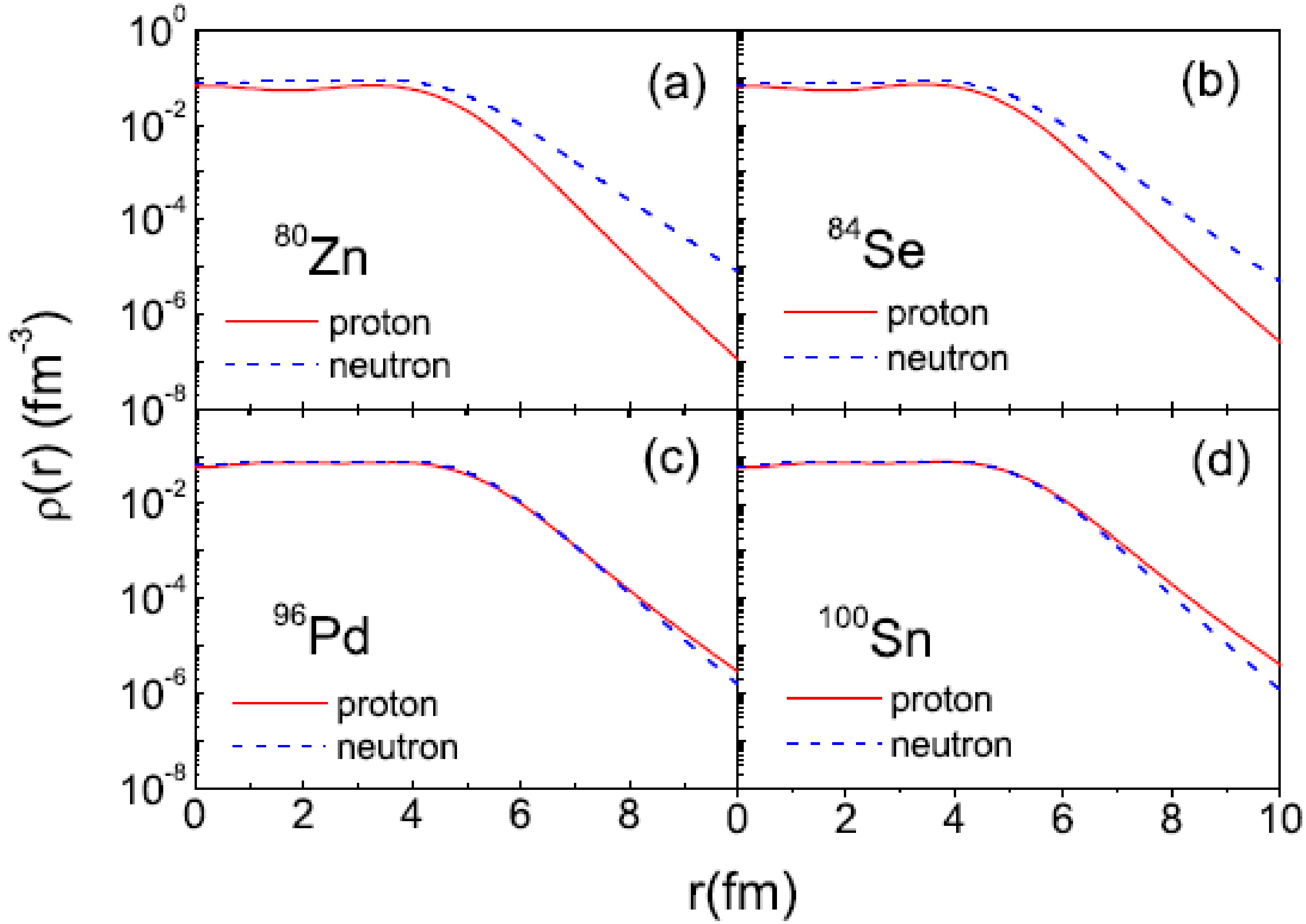
^{36}Ca

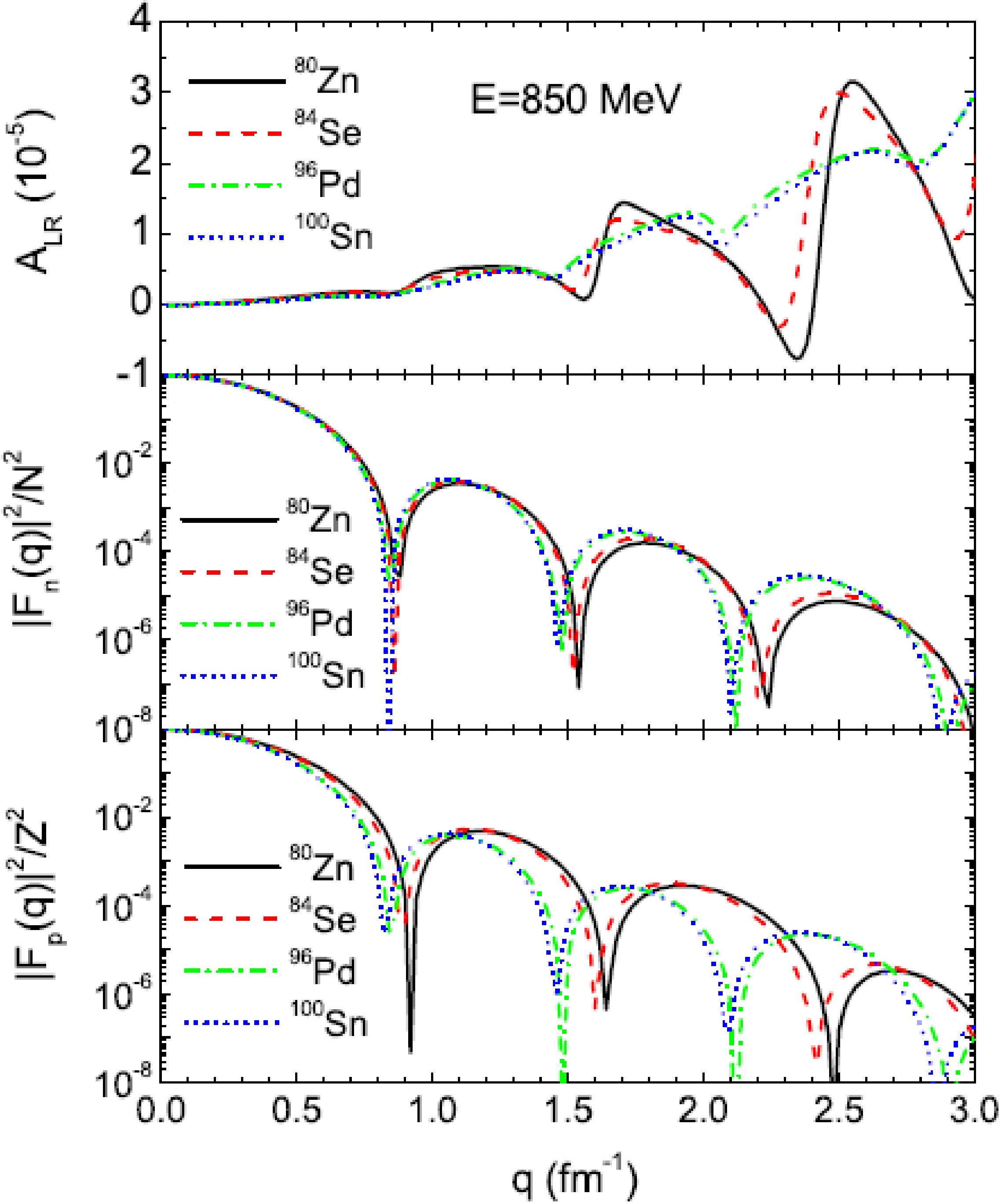
^{40}Ca

^{48}Ca

^{60}Ca

Neutron and proton densities for N=50 isotonic chain





^{80}**Zn**

^{84}**Se**

^{96}**Pd**

^{100}**Sn**

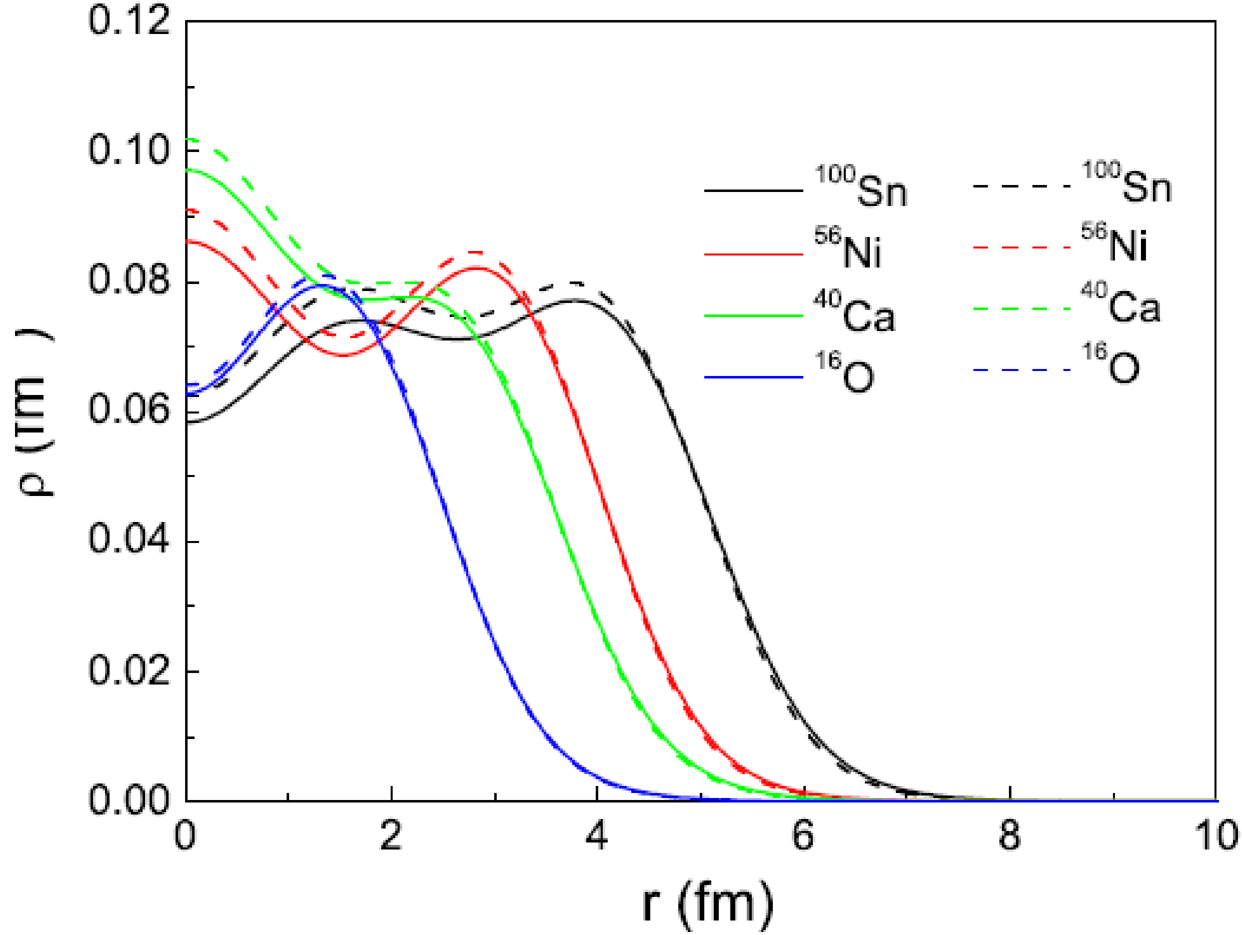
Densities of N=Z doubly magic nuclei

^{100}Sn

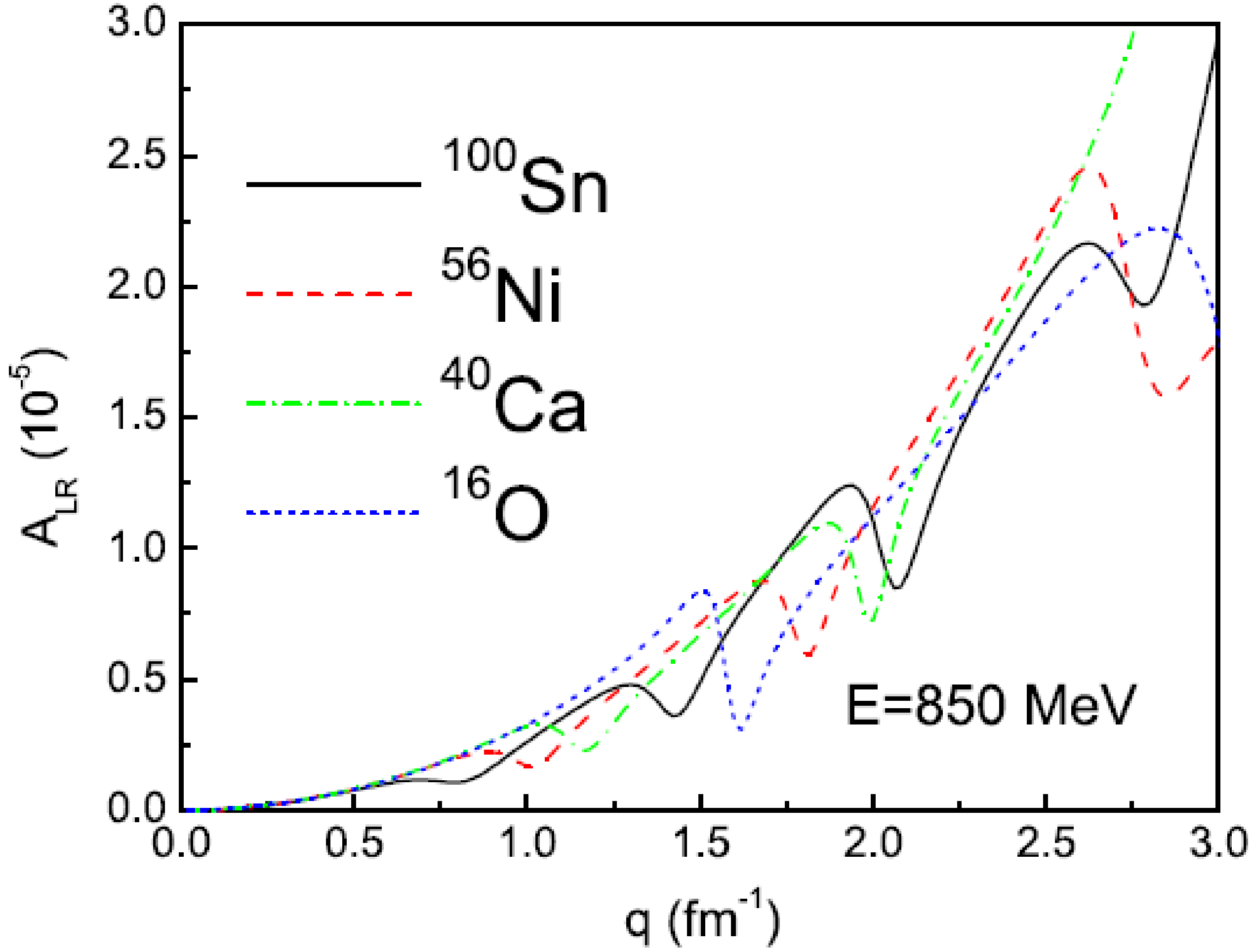
^{56}Ni

^{40}Ca

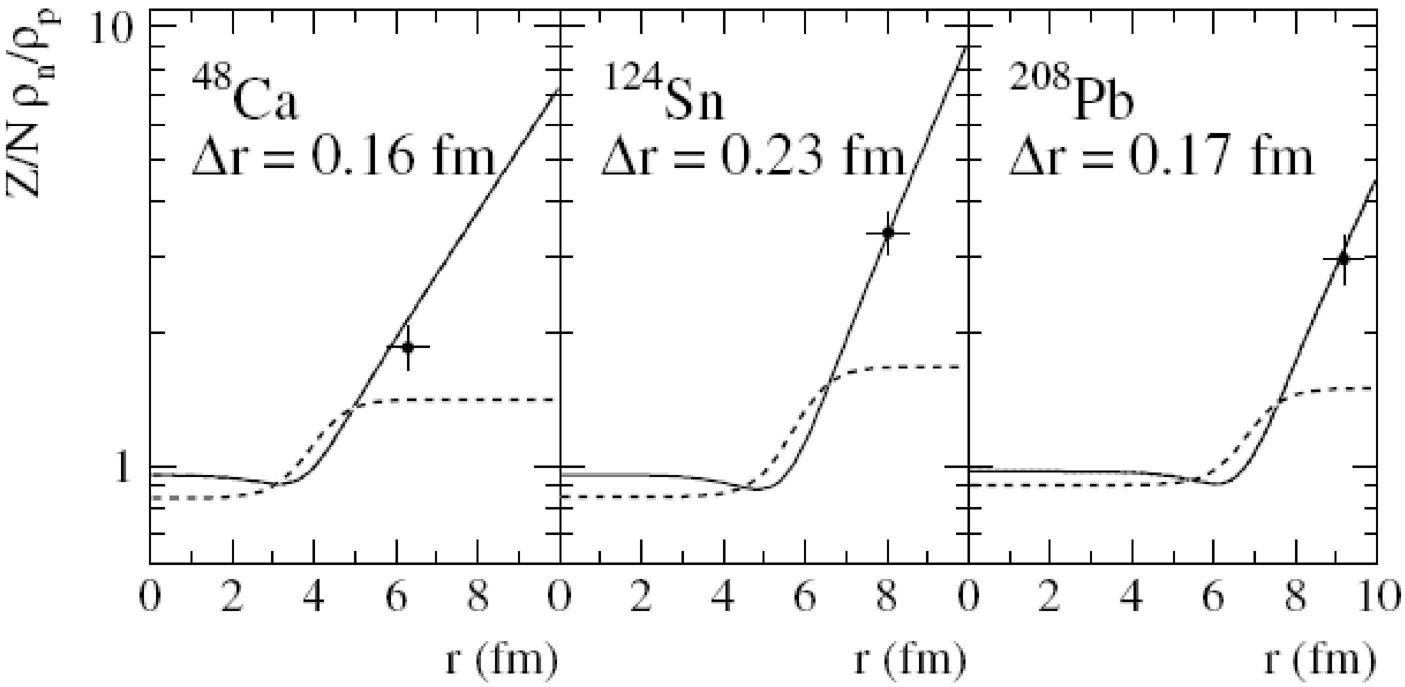
^{16}O



PVA of N=Z doubly magic nuclei

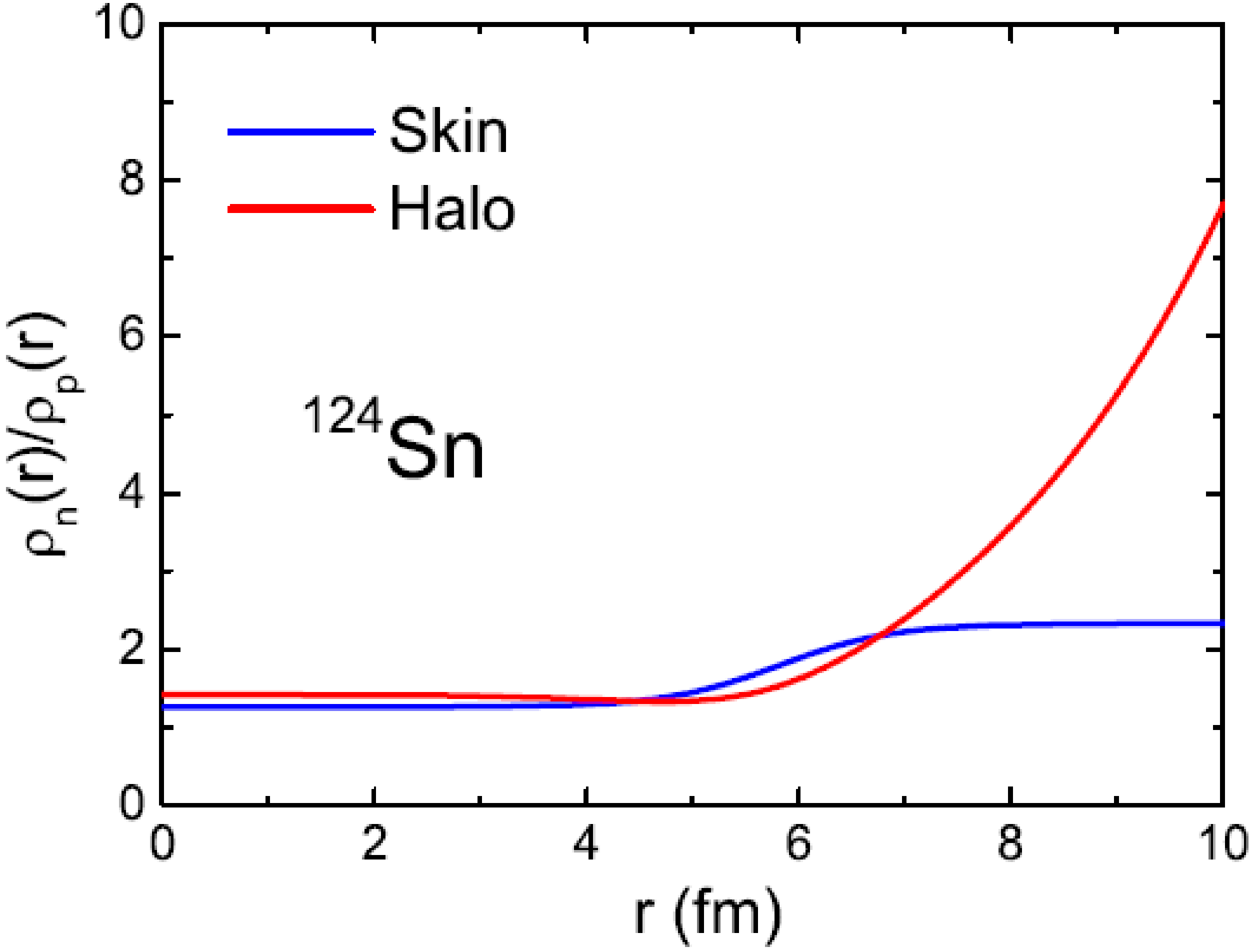


Antiproton atomic experiments show that the neutron rich nuclei favor the peripheral neutron distribution in the form of a neutron halo rather than a neutron skin.

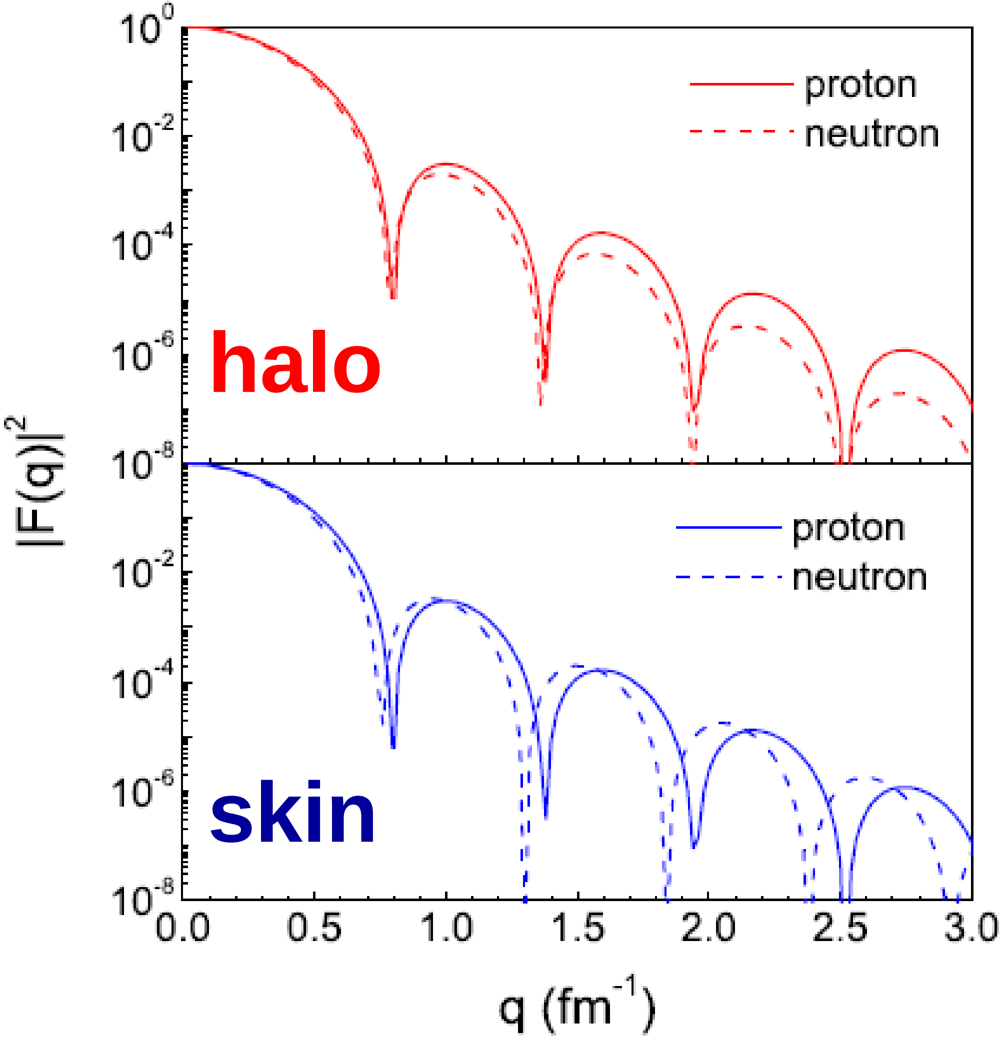


A. Trzcinsk et al., PRL 87, 082501 (2001)

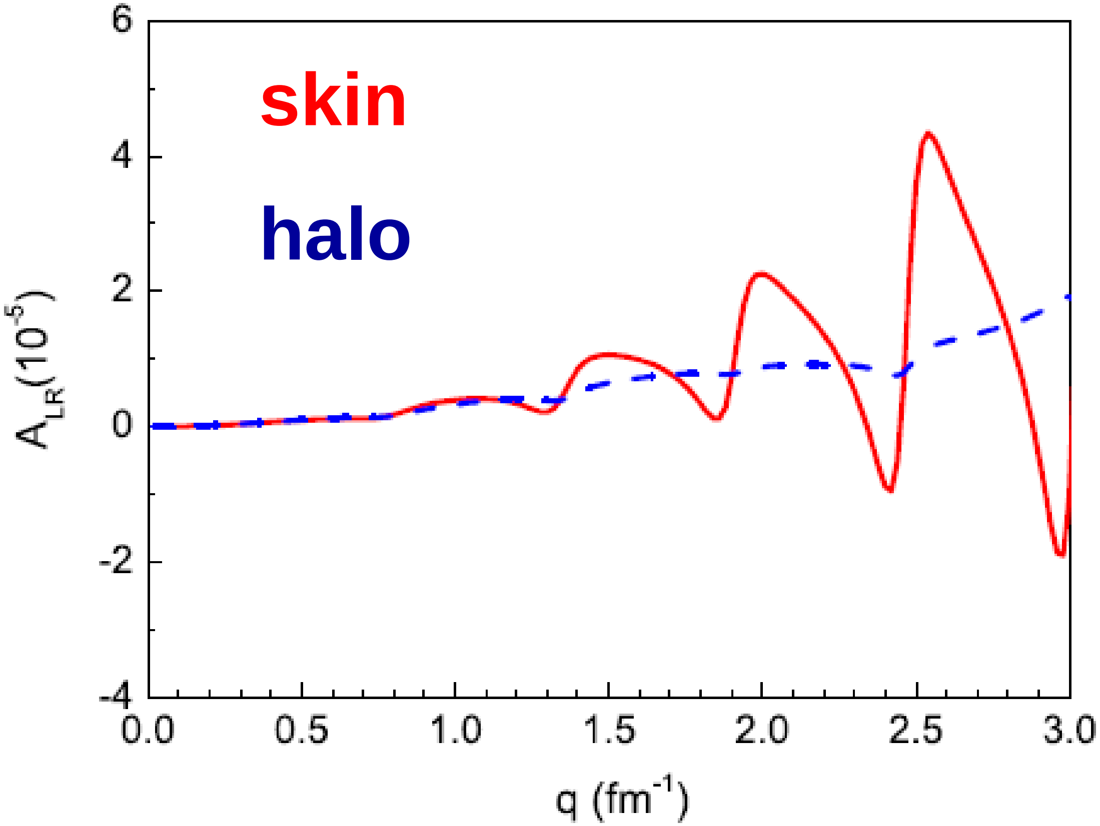
The skin and halo neutron distribution of ^{124}Sn



Form factor of ^{124}Sn with skin and halo neutron distributions



PVA of ^{124}Sn



The type of neutron distribution can be identified by the amplitude of PVA.

Focus issue on open problems in nuclear structure theory

J. Phys. G: Nucl. Part. Phys. 37 (2010) 064019

Parity-violating elastic electron scattering and nuclear structure

O Moreno[1], E Moya de Guerra[1], P Sarriguren[2] and J M Udías[1]

It has also been proposed [23] that PV electron scattering can be used to determine the type (skin or halo) of neutron distribution in neutron-rich stable nuclei. In particular, asymmetries for skin-type neutron distributions are larger than those of halo-type neutron distributions.

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J. Phys. G: Nucl. Part. Phys. 37 (2010) 064019 O Moreno *et al*

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PHYSICAL REVIEW C **95**, 044318 (2017)

Coulomb form factors of even-even nuclei described by axially deformed relativistic mean-field models

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Background: Combining the relativistic mean-field (RMF) model and distorted wave Born approximation (DWBA) method, Coulomb form factors for elastic electron scattering have been studied for several stable nuclei (^{208}Pb, ^{40}Ca, ^{32}S, and ^{24}Mg) with a methodology that can be extended to exotic nuclei.
Purpose: Previous studies on nuclear Coulomb form factors by the RMF + DWBA method were mainly based on the spherical RMF model. This work aims to further extend the studies to the axially deformed RMF model.
Method: The nuclear proton density distributions are first calculated by the deformed RMF model. Next, the axially deformed density distributions are expanded into multipole components. With the spherical ρ_0 components, the Coulomb form factors of even-even nuclei are calculated by the DWBA method.
Results: For spherical nuclei, the nuclear Coulomb form factors obtained with the deformed RMF model almost coincide with those from the spherical RMF model. For deformed nuclei, Coulomb form factors obtained with the deformed RMF model agree better with the experimental data at the diffraction minima and at high momentum transfers.
Conclusions: Results indicate the proton densities calculated from the axially deformed RMF model are valid and reasonable. The electron-scattering experiments will soon be available for exotic nuclei, and the studies in this paper are helpful to interpret the experimental data of deformed exotic nuclei.

PHYSICAL REVIEW C **90**, 024307 (2014)

Spins and parities of the odd-A P isotopes within a relativistic mean-field model and elastic magnetic electron-scattering theory

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The ground-state spins and parities of the odd-A phosphorus isotopes $^{25-47}$P are studied with the relativistic mean-field (RMF) model and relativistic elastic magnetic electron-scattering theory (REMES). Results of the RMF model with the NL-SH, TM2, and NL3 parameters show that the $2s_{1/2}$ and $1d_{3/2}$ proton level inversion may occur for the neutron-rich isotopes $^{37-47}$P, and, consequently, the possible spin-parity values of $^{37-47}$P may be $\frac{3}{2}^+$, which, except for ^{47}P, differs from those given by the NUBASE2012 nuclear data table by Audi *et al.* Calculations of the elastic magnetic electron scattering of $^{37-47}$P with the single valence proton in the $2s_{1/2}$ and $1d_{3/2}$ state show that the form factors have significant differences. The results imply that elastic magnetic electron scattering can be a possible way to study the $2s_{1/2}$ and $1d_{3/2}$ level inversion and the spin-parity values of $^{37-47}$P. The results can also provide new tests as to what extent the RMF model, along with its various parameter sets, is valid for describing the nuclear structures. In addition, the contributions of the upper and lower components of the Dirac four-spinors to the form factors and the isotopic shifts of the magnetic form factors are discussed.

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One-pion exchange current effects on magnetic form factor in the relativistic formalism

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Abstract
One-pion exchange current effects on the magnetic form factors of some odd nuclei are studied in the relativistic formalism. The Dirac wave functions of nucleons are calculated from the relativistic mean-field theory. After fitting to experimental data by quenching factors, it is found that taking the one-pion exchange currents into account gives a better description of the magnetic form factor. The root-mean-square radii of the valance nucleon orbits are also calculated in RMF model, which coincide with experimental radii extracted

Summary and Outlook

● We have investigated the elastic Coulomb, magnetic, and parity violating electron scattering by PWBA, Eikonal approximation, and phase shift analysis.

● **There are still many problems should be considered:**

- electron scattering from deformed nuclei;

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Thanks !

I am happy to visit Trento!

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Thank You！