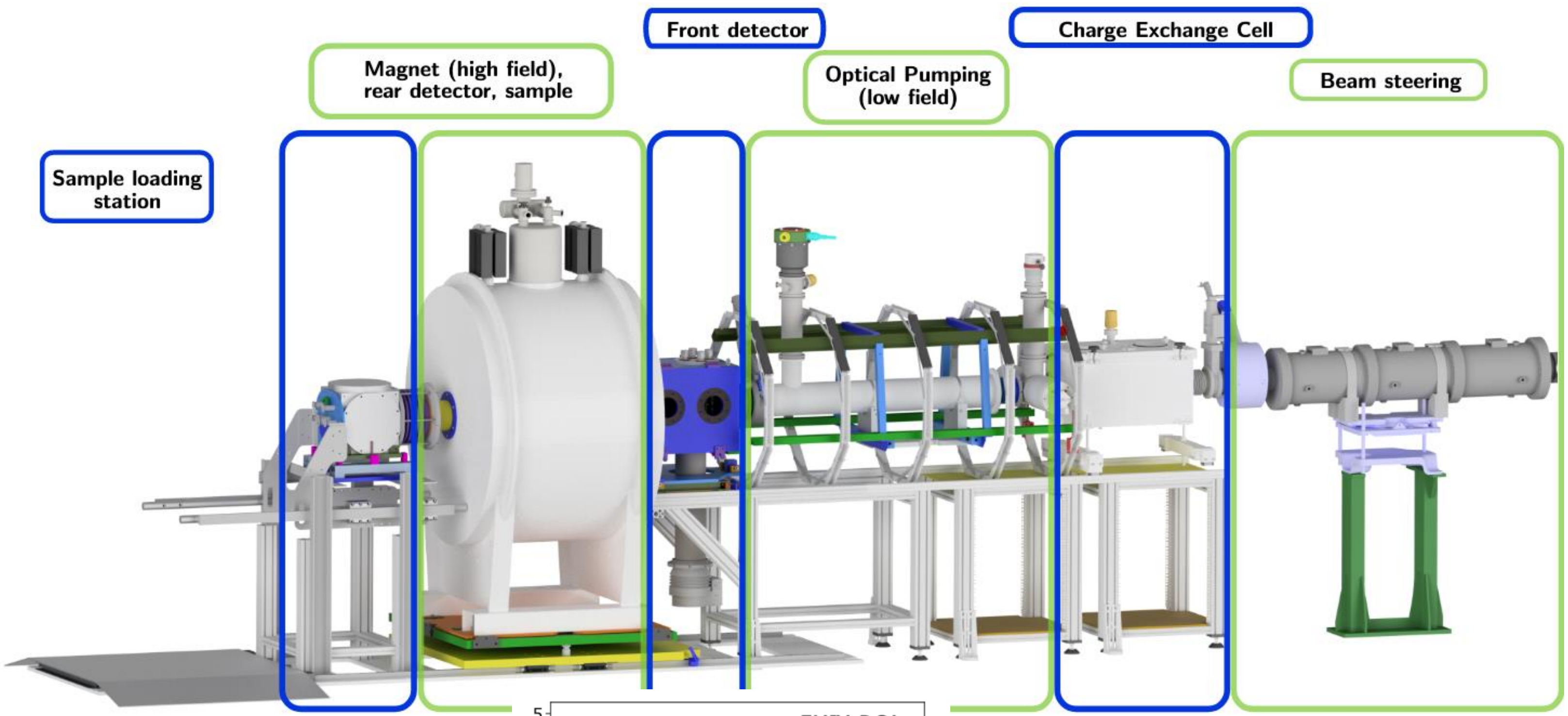
Magnetic moment of ^{11}Be with ppm accuracy

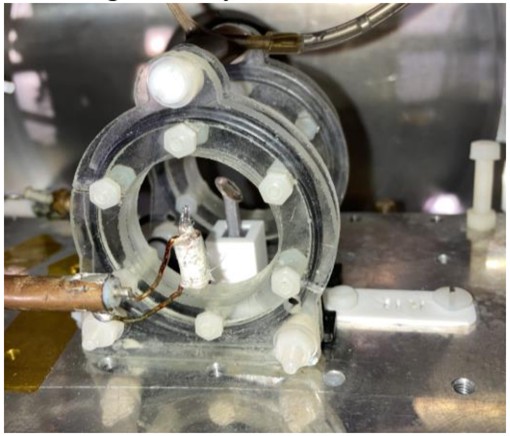
A. Antušek[1], N. Azaryan[2], M. Baranowski[3], M. L. Bissell[2], M. J. Chojnacki[2], R. P. de Groote[4], A. Hurajt[5], M. Jankowski[2], G. King[6], M. Kowalska[2], S. Pastore[6], M. Pešek[2],M. Piersa-Siłkowska[2], A. Takamine[7], T. P. Treczoks[2] , Dalibor Zakoucky[8]

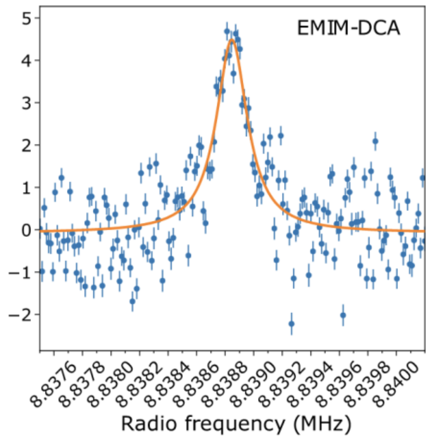
[1]Faculty of Materials Science and Technology, Slovak University of Technology, 917 24 Trnava, Slovak Republic
[2]Experimental Physics Department, CERN, 1211 Geneva, Switzerland
[3]Faculty of Physics, Adam Mickiewicz University, 61-614 Poznań, Poland
[4]Instituut voor Kern- en Stalingsfysica, KU Leuven, B-3001 Leuven, Belgium
[5]Department of Physical and Theoretical Chemistry, Faculty of Natural Sciences, Comenius University in Bratislava, 842 15 Bratislava, Slovak Republic
[6]Department of Physics, Washington University, St. Louis, Missouri 63130, USA
[7]RIKEN Nishina Center for Accelerator-Based Science, Wako, Saitama 351-0198, Japan
[8]Nuclear Physics Institute, Czech Academy of Sciences

The VITO Beamline



CAD-Design: N. Azaryan, Render: M. Jankowski





R. D Harding *et al*., PHYS. REV. X 10, 041061 (2020)

What do we know about ^{11}Be?

Physics Letters B 268 (1991) 339–344
North-Holland
PHYSICS LETTERS B

Neutron halo in ^{11}Be studied via reaction cross sections

M. Fukuda [1], T. Ichihara, N. Inabe, T. Kubo, H. Kumagai, T. Nakagawa, Y. Yano, I. Tanihata
RIKEN, 2-1 Hirosawa, Wako, Saitama 351-01, Japan

M. Adachi, K. Asahi, M. Kouguchi [2]
Department of Applied Physics, TIT, Meguro, Tokyo 152, Japan

M. Ishihara [3], H. Sagawa and S. Shimoura
Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

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PRL **102,** 062503 (2009) PHYSICAL REVIEW LETTERS week ending 13 FEBRUARY 2009

Nuclear Charge Radii of ^{7,9,10}Be and the One-Neutron Halo Nucleus ^{11}Be

W. Nörtershäuser,[1,2] D. Tiedemann,[2] M. Žáková,[2] Z. Andjelkovic,[2] K. Blaum,[3] M. L. Bissell,[4] R. Cazan,[2] G. W. F. Drake,[5] Ch. Geppert,[1,6] M. Kowalska,[7] J. Krämer,[2] A. Krieger,[2] R. Neugart,[2] R. Sánchez,[1] F. Schmidt-Kaler,[8] Z.-C. Yan,[9] D. T. Yordanov,[3] and C. Zimmermann[6]
[1]*GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany*
[2]*Institut für Kernchemie, Universität Mainz, D-55128 Mainz, Germany*
[3]*Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany*
[4]*Instituut voor Kern- en Stralingsfysica, Katholieke Universiteit Leuven, B-3001 Leuven, Belgium*
[5]*Department of Physics, University of Windsor, Windsor, Ontario, Canada, N9B 3P4*
[6]*Physikalisches Institut, Universität Tübingen, D-72076 Tübingen, Germany*
[7]*CERN, Physics Department, CH-1211 Geneva 23, Switzerland*
[8]*Quanteninformationsverarbeitung, Universität Ulm, D-89069 Ulm, Germany*
[9]*Department of Physics, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3*
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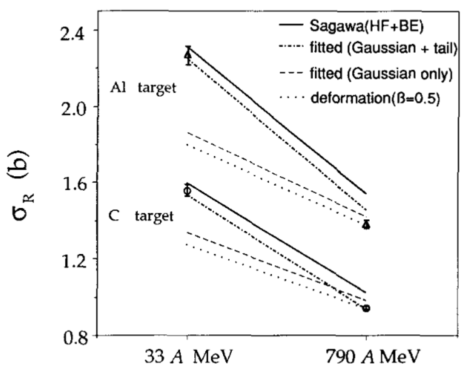
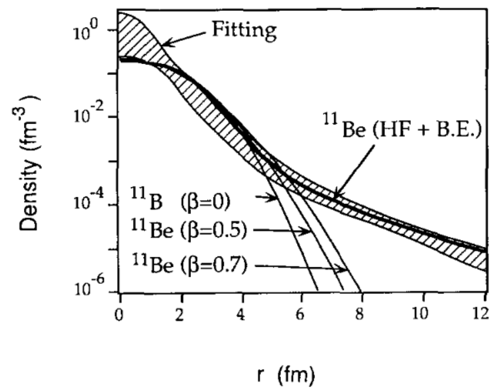
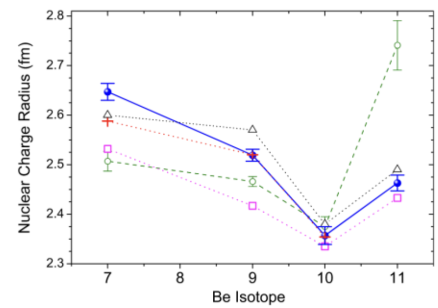
PRL **112,** 162502 (2014) PHYSICAL REVIEW LETTERS week ending 25 APRIL 2014

Hyperfine Structure Constant of the Neutron Halo Nucleus ^{11}Be^{+}

A. Takamine,[1,*] M. Wada,[1,†] K. Okada,[2] T. Sonoda,[1] P. Schury,[1] T. Nakamura,[3] Y. Kanai,[3] T. Kubo,[1] I. Katayama,[4] S. Ohtani,[5] H. Wollnik,[6] and H. A. Schuessler[7]
[1]*Nishina Center for Accelerator Based Science, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
[2]*Department of Physics, Sophia University, 7-1 Kioicho, Chiyoda, Tokyo 102-8554, Japan*
[3]*Atomic Physics Laboratory, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
[4]*Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK), 2-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*
[5]*Institute for Laser Science (ILS), The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan*
[6]*Department of Chemistry and Biochemistry, New Mexico State University, Las Cruces, New Mexico 88003, USA*
[7]*Department of Physics, Texas A&M University, College Station, Texas 77843, USA*
(Received 18 October 2012; revised manuscript received 15 January 2014; published 24 April 2014)







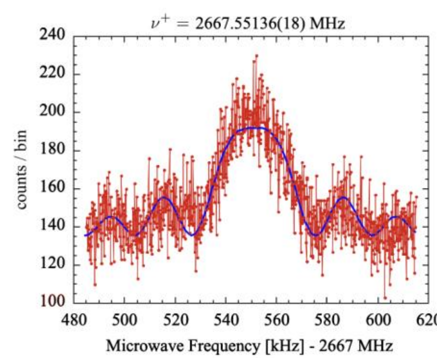
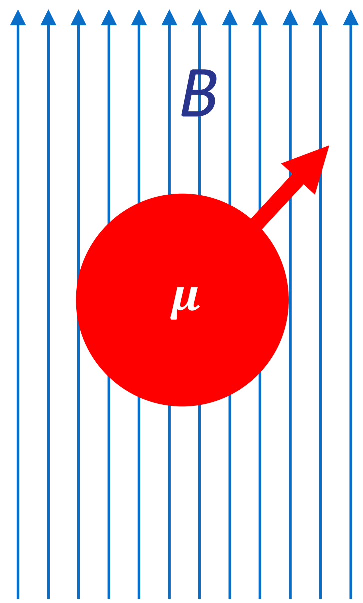


TABLE III. Magnetic hyperfine structure constants A of the ground $2s^2S_{1/2}$ state ions and nuclear magnetic moments for all odd beryllium isotopes.

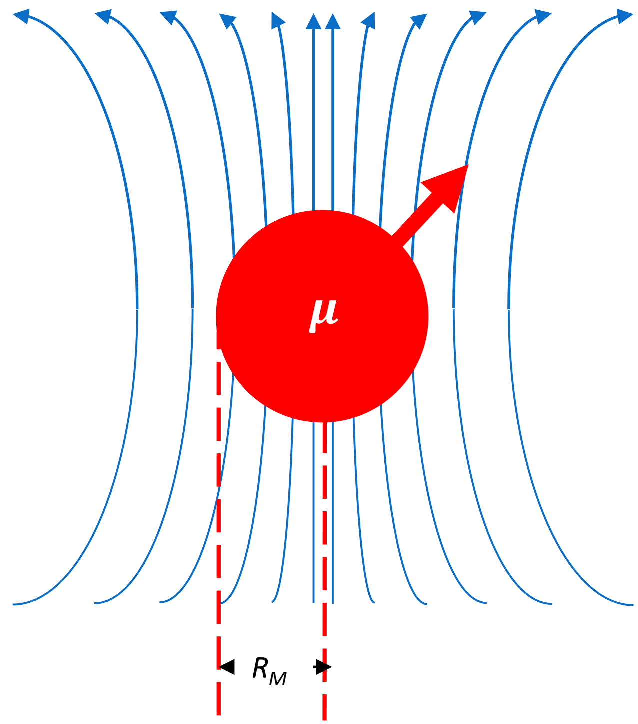
Isotope	A [MHz]	μ_I [n.m.]	$(\mu_I$ [n.m.]$)^a$
^{7}Be	−742.772 28(43)[c]		−1.399 28(2)[c]
^{9}Be	−625.008 837 048(10)[d]	−1.177 432(3)[e]	
^{11}Be	−2677.302 988(72)[b]	−1.6816(8)[f]	−1.681 66(11)[b]

[a]Indirectly from A.
[b]This work.
[c]Okada *et al.*, 2008 [8].
[d]Wineland *et al.*, 1983 [13].
[e]Itano, 1983 [14].
[f]Geithner *et al.*, 1999 [17].

What is the Hyperfine Anomaly?



$$\Delta(R_1, R_2) = \frac{A_1}{A_2} / \frac{\nu_1}{\nu_2} - 1$$



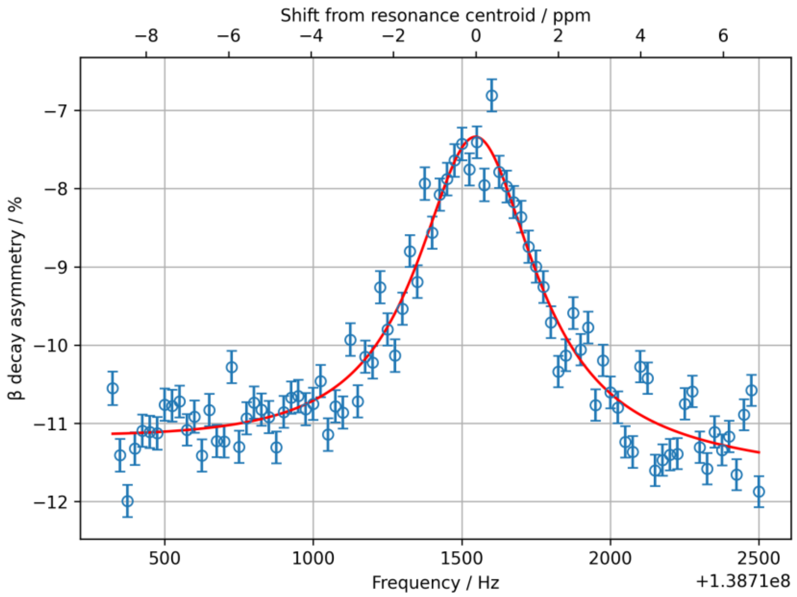
$$\frac{\nu_1}{\nu_2} = \frac{\mu_1/I_1}{\mu_2/I_2}$$

NMR

$$\frac{A_1}{A_2} = \frac{\mu_1/I_1}{\mu_2/I_2}(1 + \Delta(R_1, R_2))$$

Atomic Spectroscopy

Example from recent measurements



Literature[1] stable MNR:

$$\frac{\nu(^{39}K,\ H_2 0)}{\nu\ (D_2O)} = 0.303\,984\,85(9)$$

$$\frac{\nu(^{47}K, EMIM\ DCA)}{\nu\ (^{39}K,\ H_2O)} = 14.83852(3)$$

COLLAPS HFS measurements[2]:

$$\frac{A(^{47}K)}{A\ (^{39}K)} = 14.785(1)$$

$$^{39}\Delta^{47} = 0.364\ (9)\ \%$$

Preliminary Experimental result:

$$\frac{\nu(^{47}K, EMIM\ DCA)}{\nu\ (D_2O)} = 4.501\,684\ (9)$$

Atomic theory (Jacinda Ginges, Georgy Sanamyan)
+
Density Functional Theory (Jacek Dobaczewski)

work ongoing…

Initial calculations look extremely promising!

1) W. Sahm, A. Schwenk, Z. Nat. **29 a,** 1754 (1974)
2) J. Papuga *et al*., Phys. Rev. C **90**, 034321 (2014)

Theoretical Background

PHYSICAL REVIEW C VOLUME 59, NUMBER 1 JANUARY 1999

Hyperfine anomaly of Be isotopes and anomalous large anomaly in ^{11}Be

T. Fujita* and K. Ito†
Department of Physics, Faculty of Science and Technology, Nihon University, Tokyo, Japan

Toshio Suzuki‡
Department of Physics, College of Humanities and Sciences, Nihon University, Sakurajosui 3-25-40, Setagaya-ku, Tokyo 156-8550, Japan
(Received 10 September 1998)

A new result of investigations of the hyperfine structure (hfs) anomaly in Be isotopes is presented. The hfs constant for ^{11}Be is obtained by using the core plus neutron type wave function $|2s_{1/2}\rangle + |1d_{5/2}\times 2^+;\frac{1}{2}^+\rangle$. A large hfs anomaly of ^{11}Be is found, which is mainly due to the large radius of the halo single-particle state. [S0556-2813(99)04701-9]

PACS number(s): 21.10.Ky, 21.60.Cs, 27.20.+n, 32.10.Fn

PHYSICAL REVIEW A **89**, 032510 (2014)

Ground-state hyperfine splitting in the Be$^+$ ion

Mariusz Puchalski[1,2] and Krzysztof Pachucki[1]
[1]*Faculty of Physics, University of Warsaw, Hoża 69, 00-681 Warsaw, Poland*
[2]*Faculty of Chemistry, Adam Mickiewicz University, Grunwaldzka 6, 60-780 Poznań, Poland*
(Received 18 February 2014; published 13 March 2014)

Relativistic and QED corrections are calculated for the hyperfine splitting (hfs) in the $2S_{1/2}$ ground state of ^{9}Be$^+$ ions with an exact account for electronic correlations. The achieved accuracy is sufficient to determine the finite nuclear size effects from the comparison to the experimental hfs value. The obtained results establish the ground to determine the neutron halo in ^{11}Be.

DOI: 10.1103/PhysRevA.89.032510 PACS number(s): 31.30.J−, 31.15.ac, 21.10.Ft

PHYSICAL REVIEW C **87**, 035503 (2013)

Quantum Monte Carlo calculations of electromagnetic moments and transitions in $A \leqslant 9$ nuclei with meson-exchange currents derived from chiral effective field theory

S. Pastore,[1,*] Steven C. Pieper,[1,†] R. Schiavilla,[2,3,‡] and R. B. Wiringa[1,§]
[1]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*
[2]*Theory Center, Jefferson Laboratory, Newport News, Virginia 23606, USA*
[3]*Department of Physics, Old Dominion University, Norfolk, Virginia 23529, USA*
(Received 13 December 2012; revised manuscript received 28 February 2013; published 25 March 2013)

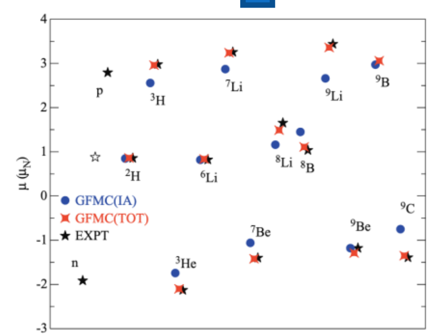
Further refinements from Perfrenova and Leclercq- Willaim[1].

$$^{9}\Delta^{11} \approx 200 \rightarrow 300\ ppm$$

State-of-the-art atomic theory

Sound theoretical prediction

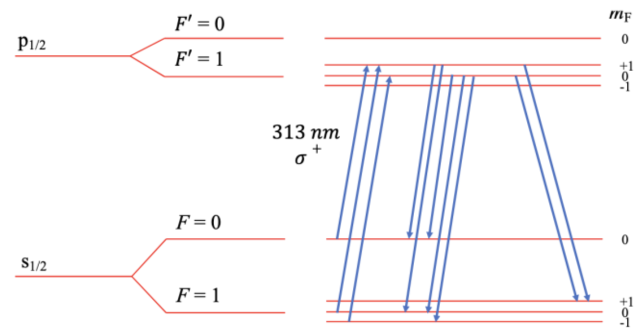
Extention of GMFC to ^{11}Be



1) Phys. Rev. C 72, 024312 (2005).

Measurement Plan

Task	Shifts
Establish the highest possible laser polarisation and β asymmetry in ^{11}Be, using single-frequency laser polarisation and subsequently laser re-pumping.	3
Locate the correct rf resonance frequency using β-NMR in the solid-state host.	1
Measure asymmetry relaxation rates in the two potential liquid hosts, BMIM-COOH and EMIM-DCA.	1
Perform rf-modulation scans in order to locate the narrow resonance in the chosen liquid and define the final modulation-free scanning range.	2
Acquire at least three independent high-resolution scans in separate liquid samples.	4



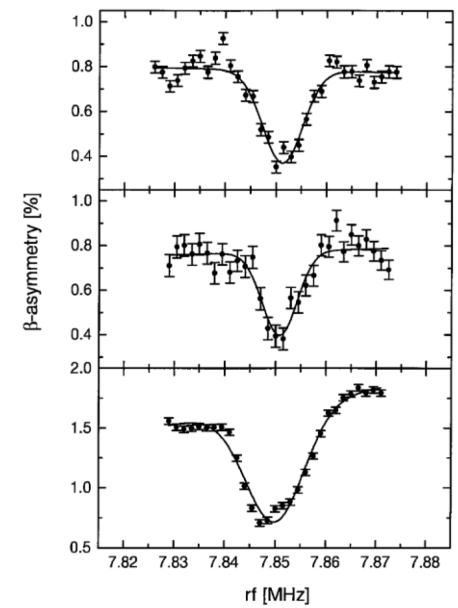


FIG. 1. Examples of β-NMR signals of ^{11}Be nuclei in a beryllium host crystal.

Geithener *et al.* [1]

<u>*11 online shifts +1 stable beam tuning*</u>

1) W Geithner *et al.*, PRL **83,** 3792 (1999)