A DYNAMICAL MODEL FOR HALO NUCLEI AND TWO-NUCLEON TRANSFER REACTIONS

F. Barranco and G. Potel

Sevilla University

R.A. Broglia

Milano University and INFN

The Niels Bohr Institute, Copenhagen

E. Vigezzi

INFN Milano

EURORIB'12

OUTLINE

- Three-body model for two-neutron halo nuclei (^{11}Li)
- Including core polarization and medium effects
- Two-nucleon transfer reactions

Properties of ^{11}Li,^{9}Li

Table 2

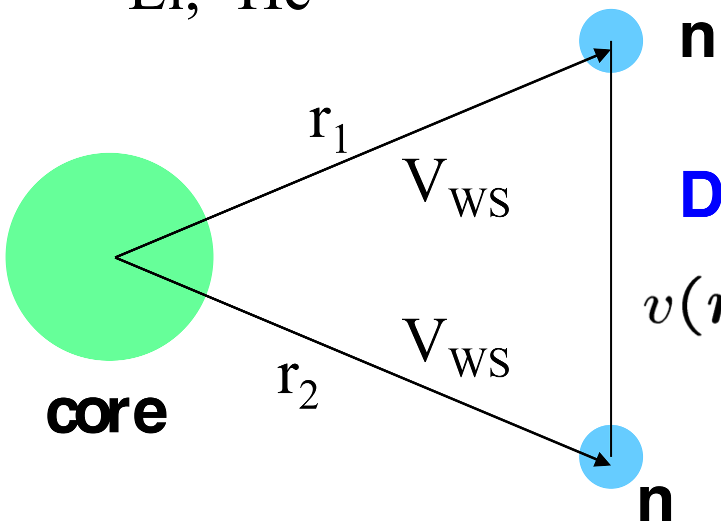
Data	Value	Refs.
S_{2n}	378 ± 5, 369.15 ± 0.65 keV	[7,8]
^{11}Li matter radius	3.27 ± 0.24, 3.12 ± 0.16, 3.55 ± 0.10 fm	[9–11]
^{9}Li matter radius	2.30 ± 0.02 fm	[10,12]
^{11}Li charge radius	2.467(37), 2.423(34), 2.426(34) fm	[13–15]
^{9}Li charge radius	2.217(35), 2.185(33) fm	[13,14]
$R^2_{ch}(n)$	-0.1161 ± 0.0022 fm^{2*}	[16]
TMD(^{10}Li)	FWHM $= 56.1 \pm 1.2$ MeV$/c$, shape	[18]
Correlation c_1	$-1.03(4)$	[18]
Correlation c_2	1.41(8)	[18]
$\mu(^{11}\text{Li})$	3.6673(25), 3.6712(3) n.m.	[19,22]
$\mu(^{9}\text{Li})$	3.43678(6) n.m.	[20]
Q_9	$-30.6(2)$ mb	[20]
Q_{11}	$-35.0(49)$, $-31.5(45)$, $-33.3(5)$ mb	[19,21,22]
Q_{11}/Q_9	1.088 ± 0.015	[22]
$\sigma 264_{-2n}$	242(8), 280(30) mb	[23,24]
$\sigma 264_{-1n}$	144(20), 170(20) mb	[23,24]
$\sigma 790_R$	1040(60), 1056(30), 1060(10) mb	[9,25,26]
$\sigma 790_{-2n}$	213(21), 220(10) mb	[25,26]

* A small and positive $R^2_{ch}(n) = 0.012$ fm^2 has been obtained in [17] with new model of the nucleon quark structure.

Three-body model with density-dependent delta force

G.F. Bertsch and H. Esbensen,
Ann. of Phys. 209('91)327
H. Esbensen, G.F. Bertsch, K. Hencken,
Phys. Rev. C56('99)3054

^{11}Li, ^{6}He

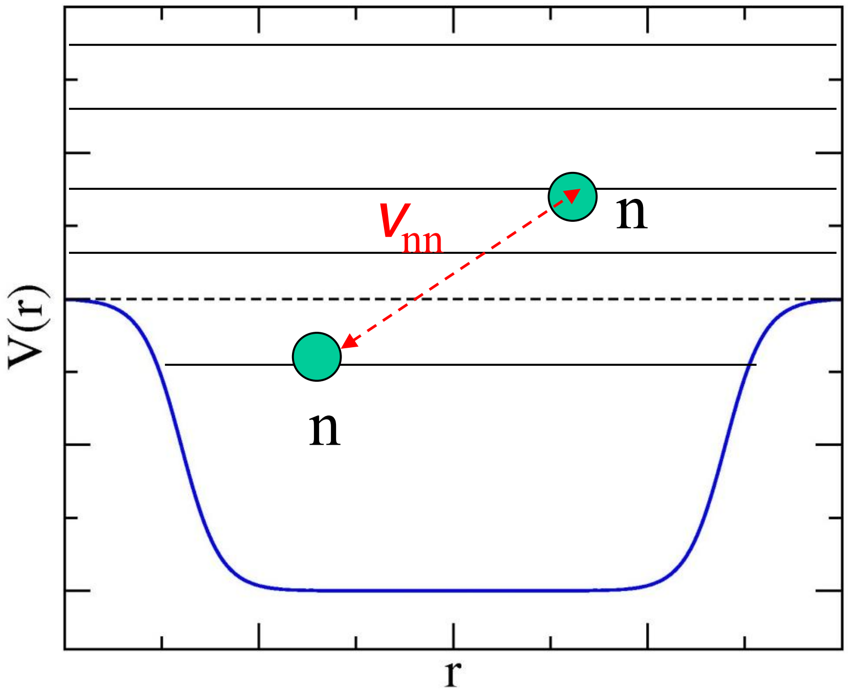


Density-dependent delta-force

$$v(\boldsymbol{r}_1, \boldsymbol{r}_2) = v_0(1 + \alpha\rho(r)) \times \delta(\boldsymbol{r}_1 - \boldsymbol{r}_2)$$

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$



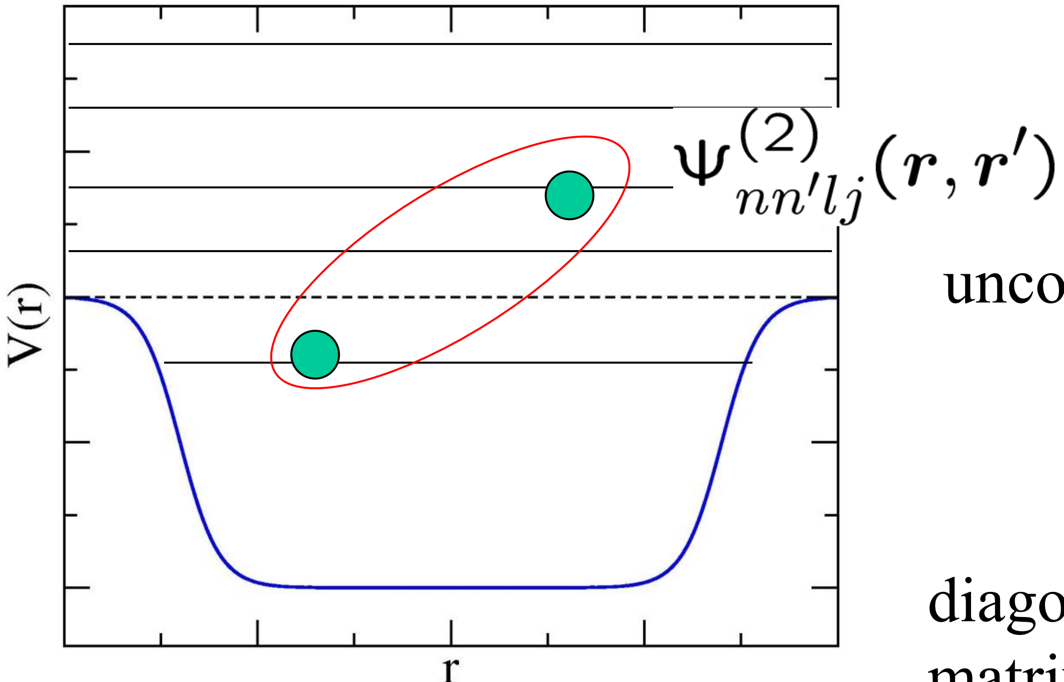
continuum states:
discretized in a large box

$$V_{nn}(\boldsymbol{r}_1, \boldsymbol{r}_2) = \delta(\boldsymbol{r}_1 - \boldsymbol{r}_2)\left(v_0 + \frac{v_\rho}{1 + \exp[(r_1 - R_\rho)/a_\rho]}\right)$$

- ✓ contact interaction
- ✓ v_0: free n-n
- ✓ density dependent term: medium many-body effects

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$

$$\Psi_{gs}(\boldsymbol{r}, \boldsymbol{r}') = \mathcal{A} \sum_{nn'lj} \alpha_{nn'lj} \, \Psi^{(2)}_{nn'lj}(\boldsymbol{r}, \boldsymbol{r}')$$



uncorrelated basis

⇩

diagonalization of Hamiltonian matrix

Good agreement with Faddeev calculations

TABLE I. Ground state properties of ^{11}Li obtained with the shallow neutron-core potential (4.1). All of our calculations employ a radial box of 40 fm; the cutoff in the two-particle spectrum is 15 MeV, except in line 6. Line 7 is the no-recoil limit corresponding to line 5.

Line	Comments	a_{nn} (fm)	S_{2n} (keV)	$\langle r^2_{c,2n} \rangle$ (fm^2)	$\langle r^2_{n,n} \rangle$ (fm^2)	$(s_{1/2})^2$ (%)
1	HHM [10]	−18.5	300	25.0	60.8	98.4
2	Faddeev [11]	−18.5	318	28.1	62.4	95.1
3	$v_\rho=0$	−18.5	569	20.3	49.0	92.1
4	$v_\rho=0$	−9.81	318	26.0	65.3	93.5
5	$v_\rho \neq 0$	−15.0	318	28.3	67.1	92.4
6	$v_\rho \neq 0$, $E_{cut}=25$ MeV	−15.0	318	27.6	62.9	91.1
7	line 5, no recoil	−15.0	318	25.3	67.9	94.4

H. Esbensen, G.F. Bertsch, K. Hencken, Phys. Rev. C 56 (1997) 3054

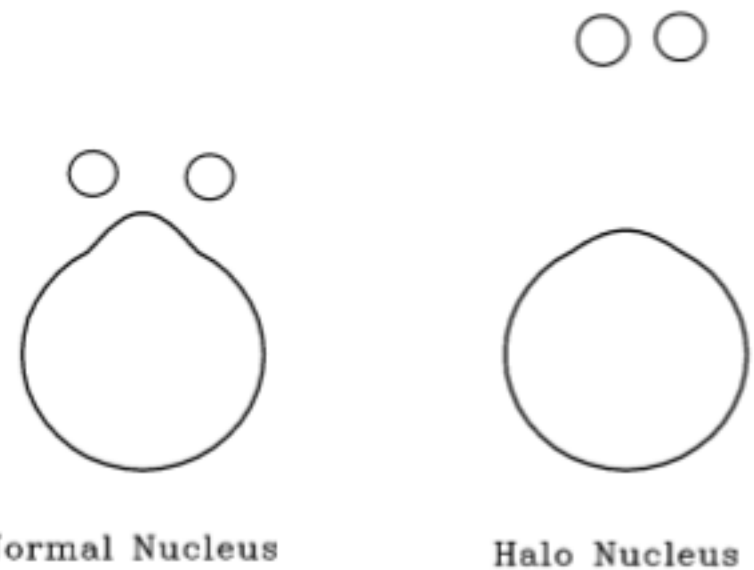
To what extent is this picture correct?

VOLUME 78, NUMBER 14 PHYSICAL REVIEW LETTERS 7 APRIL 1997

Suppression of Core Polarization in Halo Nuclei

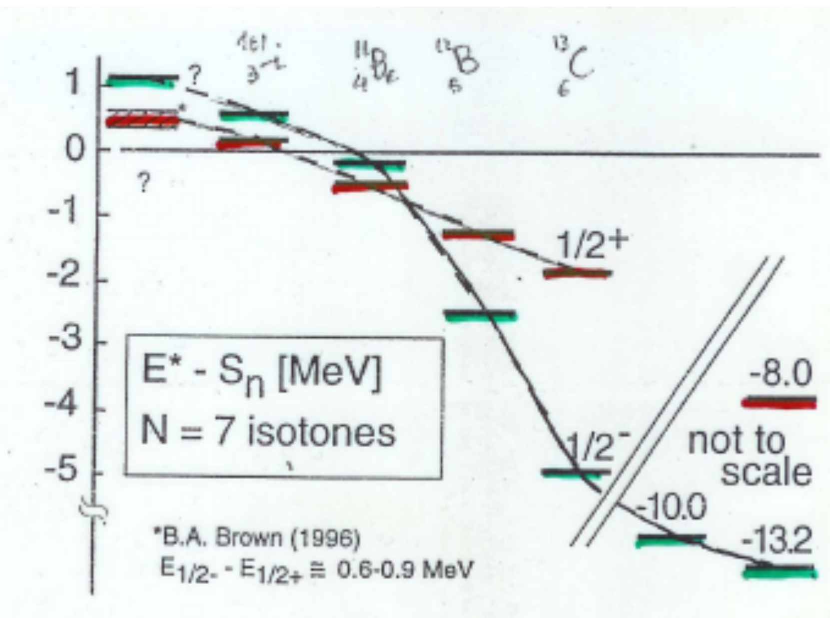
T. T. S. Kuo,[1] F. Krmpotić,[2] and Y. Tzeng[3]
[1]*Department of Physics, SUNY-Stony Brook, Stony Brook, New York 11794*
[2]*Departamento de Fisica, Facultad de Ciencias Exactas, Universidad Nacional de La Plata, C. C. 67, 1900 La Plata, Argentina*
[3]*Institute of Physics, Academia Sinica, Nankang, Taipei, Taiwan*
(Received 18 June 1996; revised manuscript received 8 October 1996)

Halo nuclei are studied using a G-matrix interaction derived from the Paris and Bonn potentials and employing a two-frequency shell model approach. It is found that the core-polarization effect is dramatically suppressed in such nuclei. Consequently, the effective interaction for halo nucleons is almost entirely given by the bare G matrix alone, which presently can be evaluated with a high degree of accuracy. The experimental pairing energies between the two halo neutrons in ^{6}He and ^{11}Li nuclei are satisfactorily reproduced by our calculation. It is suggested that the fundamental nucleon-nucleon interaction can be probed in a clearer and more direct way in halo nuclei than in ordinary nuclei.

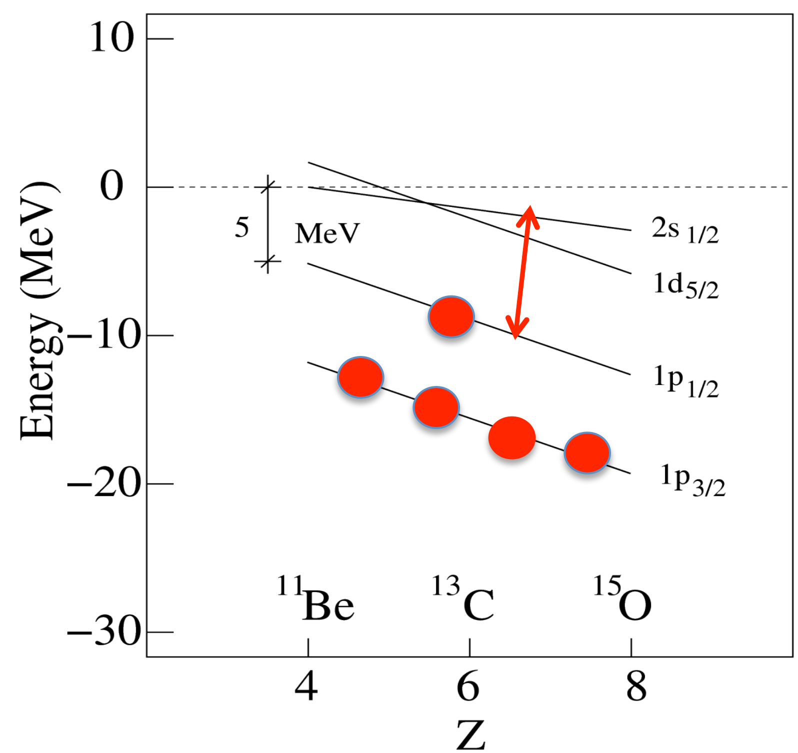


Parity inversion in N=7 isotones

Experimental systematics



Mean-field results
(Sagawa,Brown,Esbensen PLB 309(93)1)



Admixture of $d_{5/2}$ x 2^+ configuration in the $1/2^+$ g.s. of ^{11}Be is about 20%

Calculated ground state

$$|1/2+\rangle = \sqrt{0.87}\,|s_{1/2}\rangle + \sqrt{0.13}\,|d_{5/2}\otimes 2+\rangle$$

Exp.:

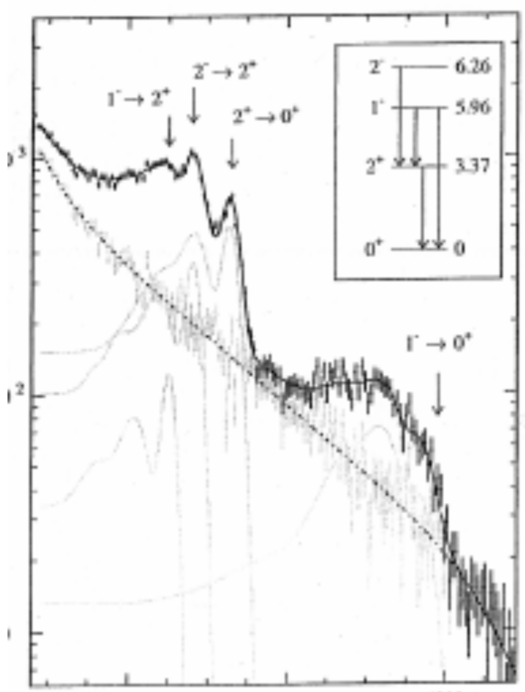
J.S. Winfield et al., Nucl.Phys. **A683** (2001) 48

$$|1/2+\rangle = \sqrt{0.84}\,|s_{1/2}\rangle + \sqrt{0.16}\,|d_{5/2}\otimes 2+\rangle$$

$^{11}Be(p,d)^{10}Be$ in inverse kinematic detecting both the ground state and the 2+ excited state of ^{10}Be.

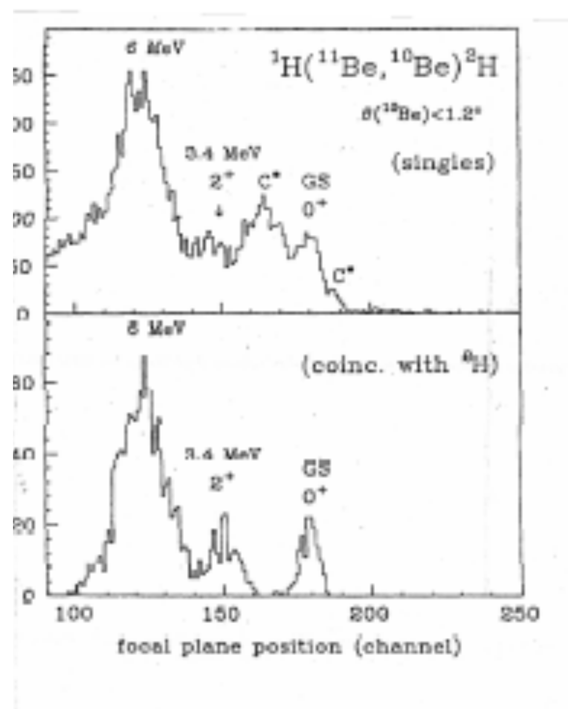
9Be(11Be,10Be+ γ) X

T. Aumann et al.
PRL 84(2000)35



p(11Be,10Be)d

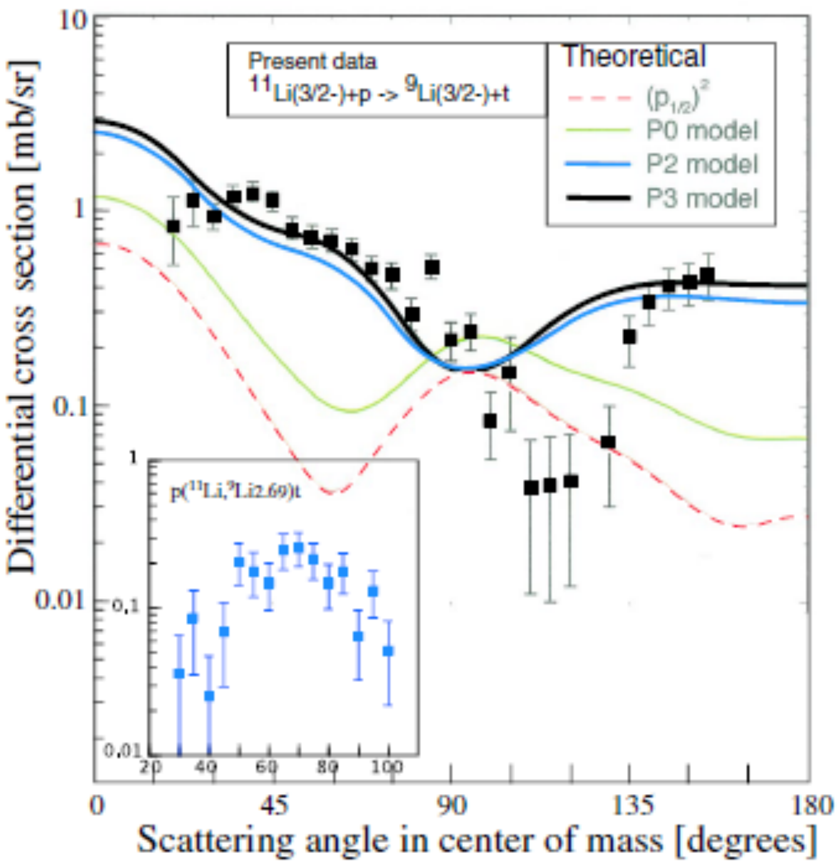
S. Fortier et al.
Phys. Lett.B461(1999)22



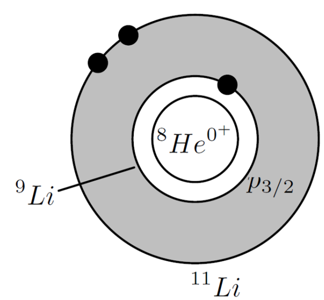
PRL 100, 192502 (2008) PHYSICAL REVIEW LETTERS week ending 16 MAY 200

Measurement of the Two-Halo Neutron Transfer Reaction $^1H(^{11}Li, ^9Li)^3H$ at 3A MeV

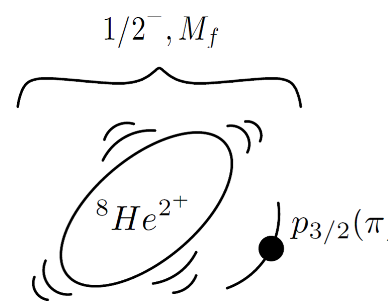
I. Tanihata,* M. Alcorta,† D. Bandyopadhyay, R. Bieri, L. Buchmann, B. Davids, N. Galinski, D. Howell,



The cross section for transitions to the first excited state (Ex = 2.69 MeV) is shown also in Fig. 3. If this state were populated by a direct transfer, it would indicate that a 1^+ or 2^+ halo component is present in the ground state of $^{11}Li(\frac{3}{2}^-)$, because the spin-parity of the ^9Li first excited state is $\frac{1}{2}^-$. This is new information that has not yet been observed in any of previous investigations. A compound



Schematic depiction of ^{11}Li



First excited state of ^9Li

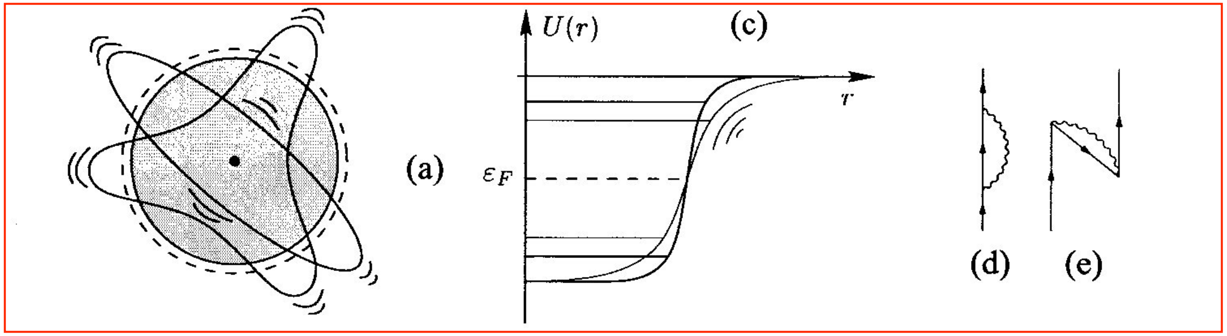
Relax some of the assumptions of Bertsch and Esbensen:

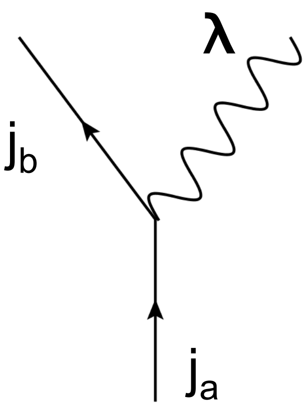
Inert core	Low-lying collective modes of the core taken into account
Different potentials for s- and p- waves	Standard mean field potential
Zero range interaction, with ad hoc density dependence	Bare N-N interaction (Argonne)

H. Esbensen, G.F. Bertsch, K. Hencken, Phys. Rev. C 56 (1997) 3054

^{10}Li, ^{11}Li F. Barranco et al. EPJ A11 (2001) 385
^{11}Be, ^{12}Be G. Gori et al. PRC 69 (2004) 041302(R)

Include particle-vibration coupling





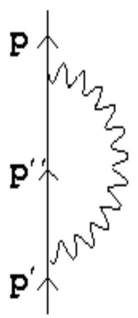
Mean field potential

$$= \frac{1}{\sqrt{4\pi}} \langle j_a \lambda | j_b \rangle \beta_\lambda \left\langle j_a \left| \frac{\partial U}{\partial r} \right| j_b \right\rangle = h(a, b\lambda)$$

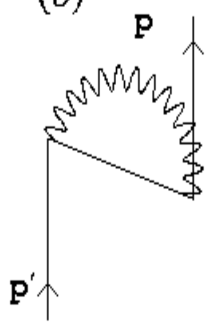
From B(EL) experimental value
in the core nucleus

SELF ENERGY RENORMALIZATION OF SINGLE-PARTICLE STATES: CLOSED SHELL

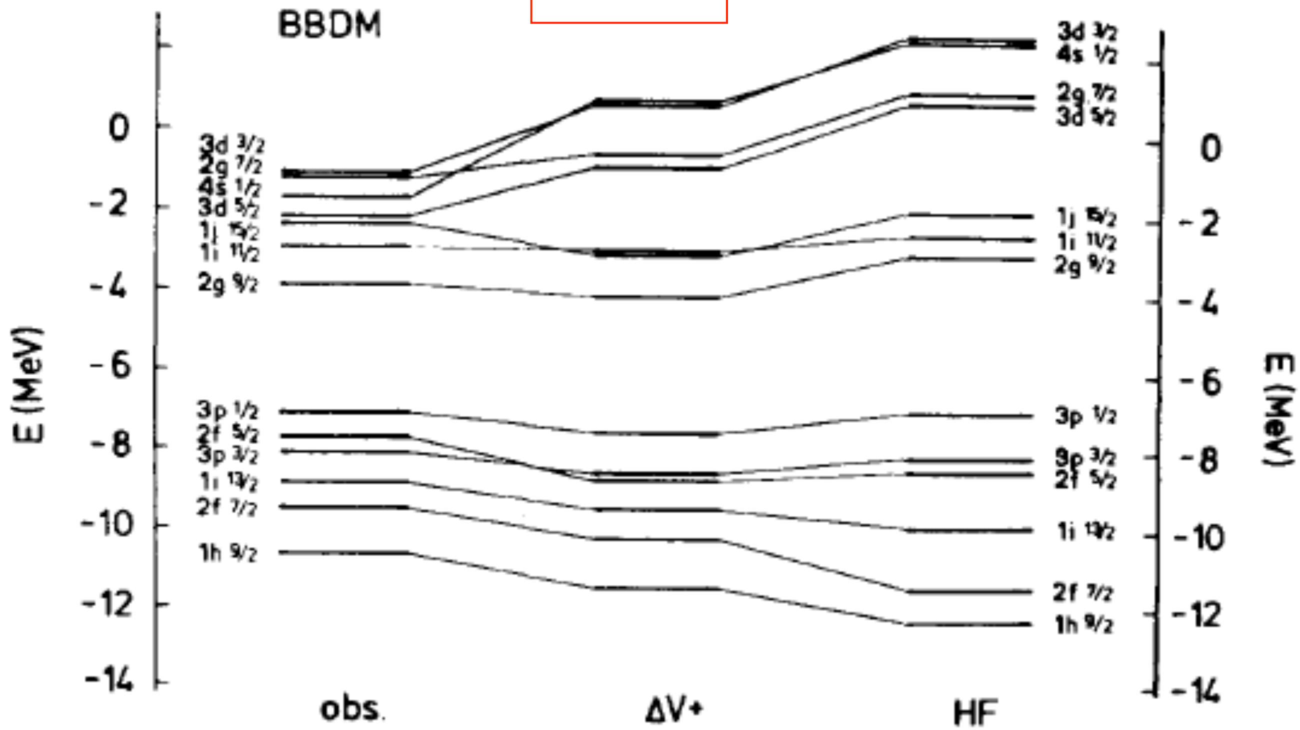
(a)



(b)



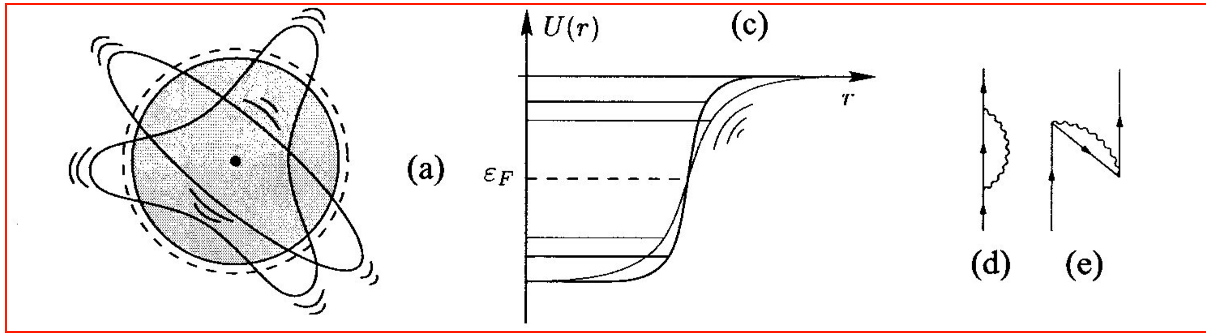
^{208}Pb



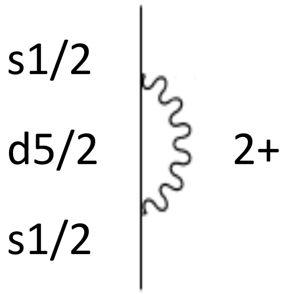
C. Mahaux, P.F. Bortignon, R.A. Broglia, C.H. Dasso and Mahaux, Phys. Rep.(1985)1

^{11}Be

Eshift = - 2.5 MeV



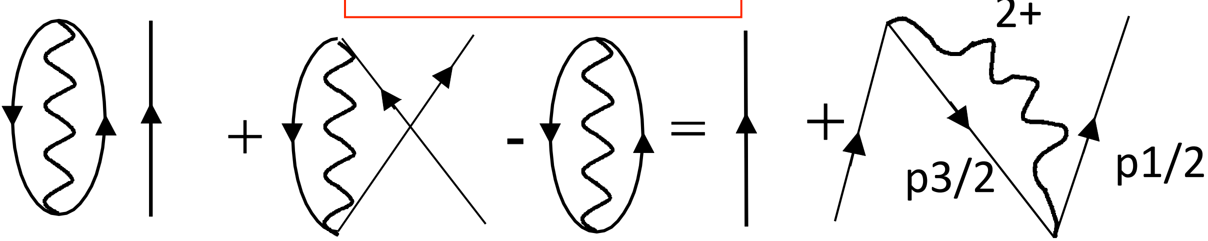
H. Sagawa et al., PLB 309 (1993)1



Self-energy

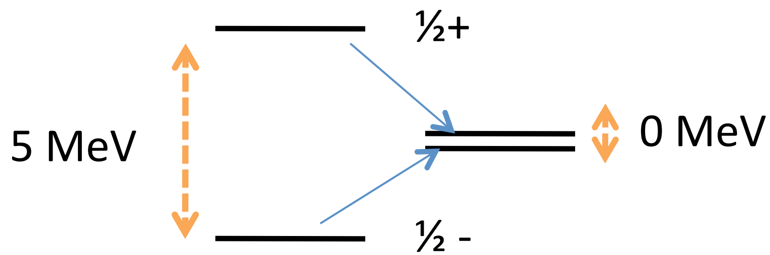
+

Eshift = + 2.5 MeV



Pauli blocking of core ground state correlations

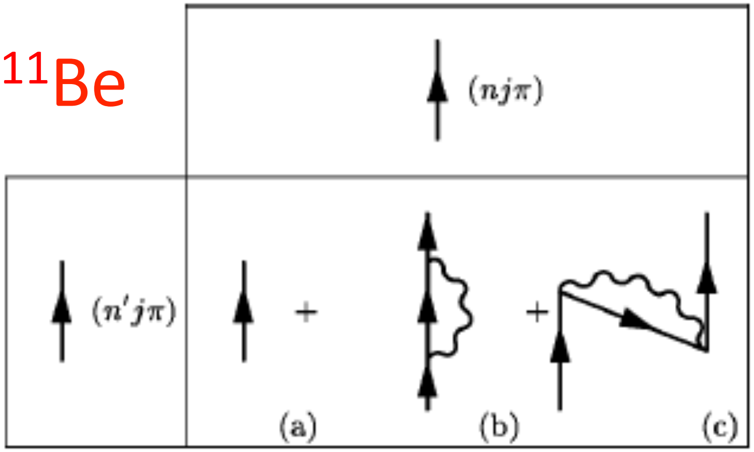
↓



Level inversion

Effective, energy-dependent matrix (Bloch-Horowitz)

^{11}Be



Main ingredients of our calculation

Fermionic degrees of freedom:

• s1/2, p1/2, d5/2 Wood-Saxon levels up to 150 MeV (discretized continuum) from a standard (Bohr-Mottelson) Woods-Saxon potential

Bosonic degrees of freedom:

• 2+ and 3- QRPA solutions with energy up to 50 MeV; residual interaction: multipole-multipole separable with the coupling constant tuned to reproduce E(2+)=3.36 MeV and $0.6<\beta_2<0.7$

A dynamical description of two-neutron halos

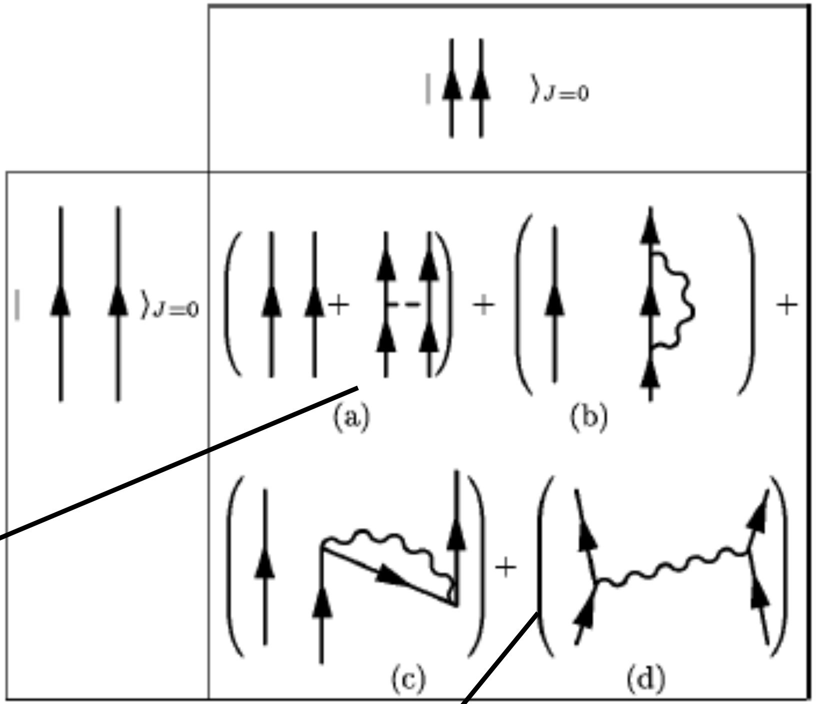
^{11}Li

F. Barranco et al. EPJ A11 (2001) 385

^{12}Be

G. Gori et al. PRC 69 (2004) 041302(R)

Energy-dependent matrix



Bare interaction

Induced interaction

Theoretical calculation for ^{10}Li and ^{11}Li

Low-lying dipole strength

↓

s-p mixing

Phenomenological input:
properties of collective models

Predictions:
binding energy,
spectroscopic factors

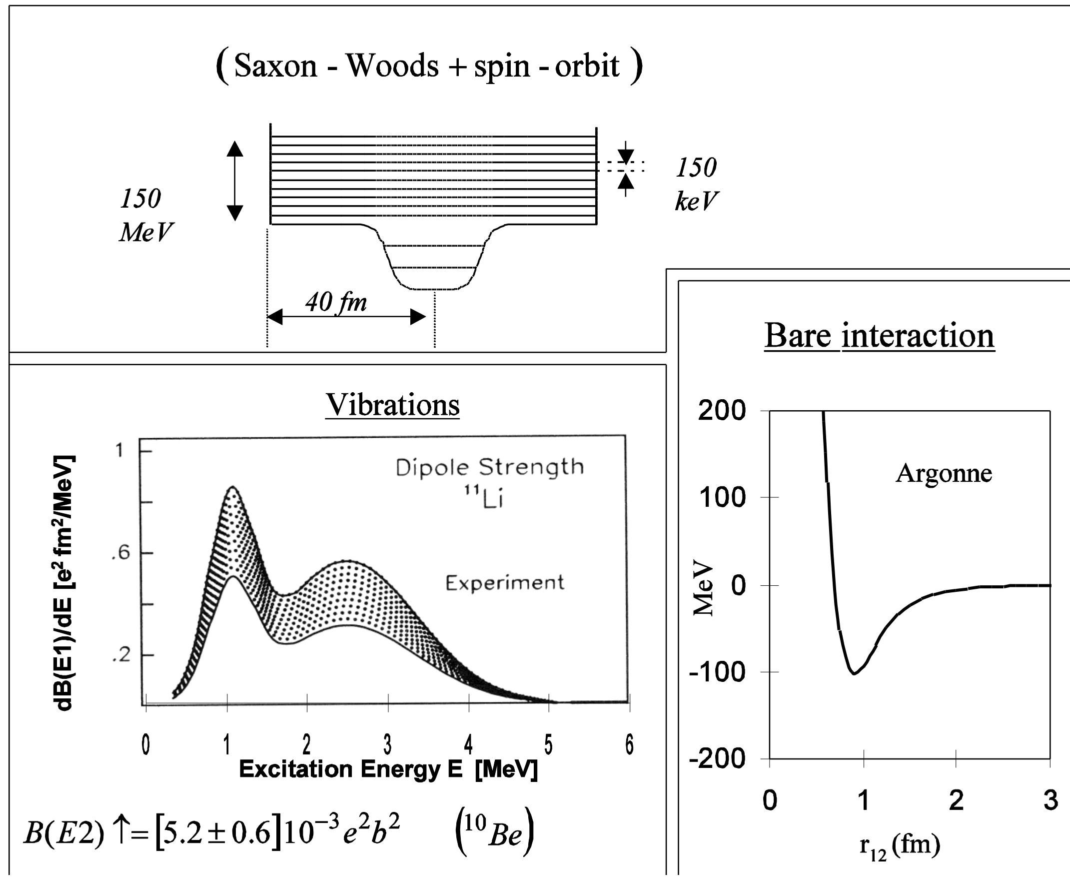


Table 2. RPA wave function of the collective low-lying quadrupole phonon in ^{11}Li, of energy $E_{2^+} = 5.05$ MeV, and leading to the most important contribution to the induced interaction in fig. 1, II. All the listed amplitudes refer to neutron transitions, except for the last column. We have adopted the self-consistent value ($\chi_2 = 0.013\,\mathrm{MeV}^{-1}$) for the coupling constant. The resulting value for the deformation parameter is $\beta_2 = 0.5$.

	$1p_{3/2}^{-1}1p_{1/2}$	$2s_{1/2}^{-1}5d_{3/2}$	$1p_{1/2}^{-1}6p_{3/2}$	$2s_{1/2}^{-1}3d_{5/2}$	$2s_{1/2}^{-1}5d_{5/2}$	$1p_{3/2}^{-1}1p_{1/2}$ (π)
X_{ph}	0.824	0.404	0.151	0.125	0.126	0.16
Y_{ph}	0.119	0.011	−0.002	−0.049	−0.011	0.07

B(E1) calculated with separable force; coupling constant tuned to reproduce experimental strength;
part of the strength comes from admixture of GDR

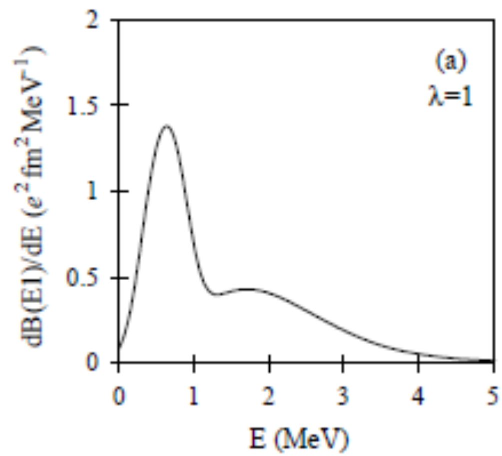
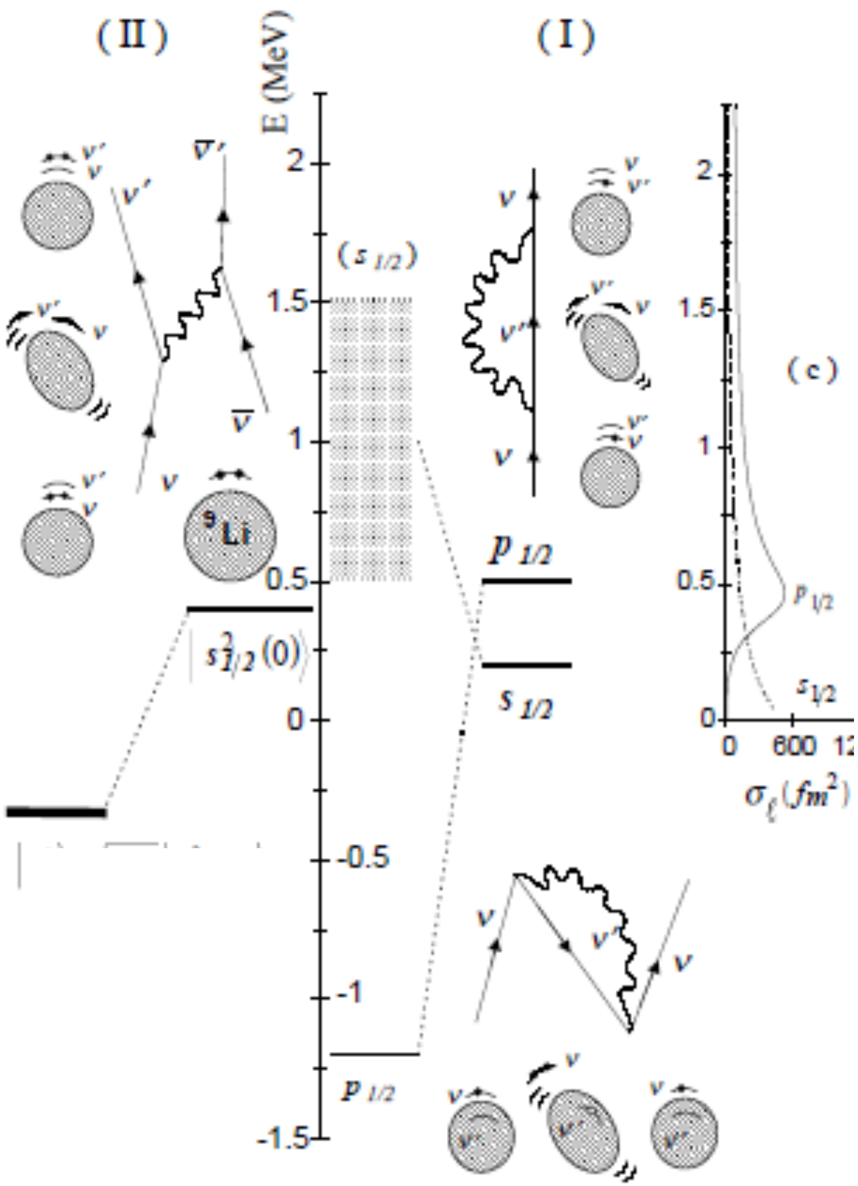


Table 3. RPA wave function of the strongest low-lying dipole vibration of ^{11}Li, ($E_{1^-} = 0.75$ MeV), and contributing most importantly to the pairing induced interaction (fig. 1, II). All the listed amplitudes refer to neutron transitions. We have used the value χ_1= 0.0043 MeV^{-1} for the isovector coupling constant in order to get a good agreement with the experimental findings. To be noted that this value coincides within 25% close to the selfconsistent value of 0.0032 MeV^{-1}. The resulting strength function (cf. fig. 2(a)) integrated up to 4 MeV gives 7% of the Thomas-Reiche-Kuhn energy weighted sum rule, to be compared to the experimental value of 8% [38].

	$1p_{1/2}^{-1}2s_{1/2}$	$1p_{1/2}^{-1}3s_{1/2}$	$1p_{1/2}^{-1}4s_{1/2}$	$1p_{1/2}^{-1}1d_{3/2}$	$1p_{3/2}^{-1}5d_{5/2}$	$1p_{3/2}^{-1}6d_{5/2}$	$1p_{3/2}^{-1}7d_{5/2}$
X_{ph}	0.847	−0.335	0.244	0.165	0.197	0.201	0.157
Y_{ph}	0.088	0.060	0.088	0.008	0.165	0.173	0.138

Results for ^{10}Li and ^{11}Li



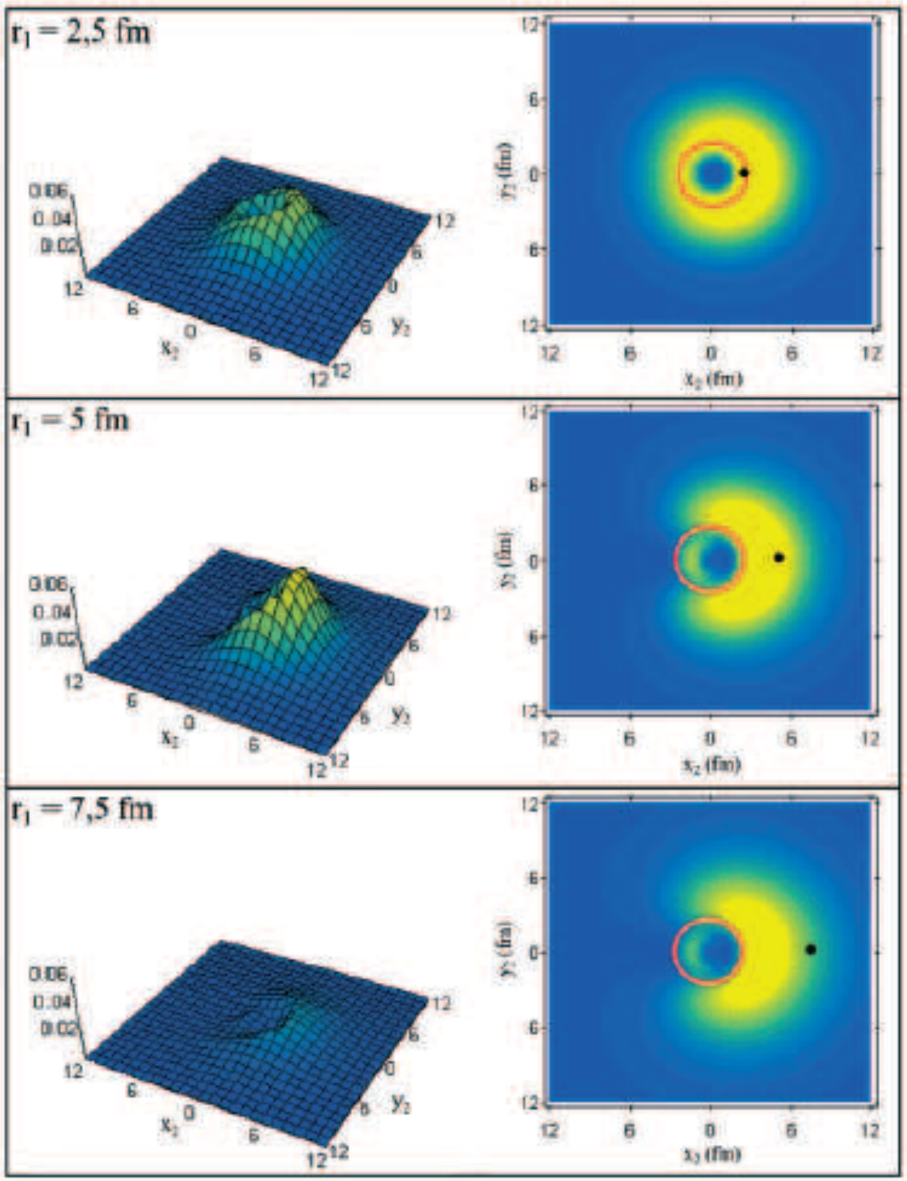
		Exp.	Theory	
			particle-vibration +Argonne	mean field
$^{10}_{3}$Li$_7$ (not bound)	s	0.1-0.2 MeV	0.2 MeV (virtual)	~ 1 MeV (virtual)
	p	0.5-0.6 MeV	0.5 MeV (res.)	-1.2 MeV (bound)
$^{11}_{3}$Li$_8$ (bound)	S_{2n}	0.369 MeV	0.33 MeV	2.4 MeV
	s^2,p^2	50% , 50%	41% , 59%	0% , 100%
	$\langle r^2\rangle^{1/2}$	3.55±0.1 fm	3.9 fm	
	$\Delta p_\perp$	48±10 MeV/c	55 MeV/c	

11Li correlated wave function

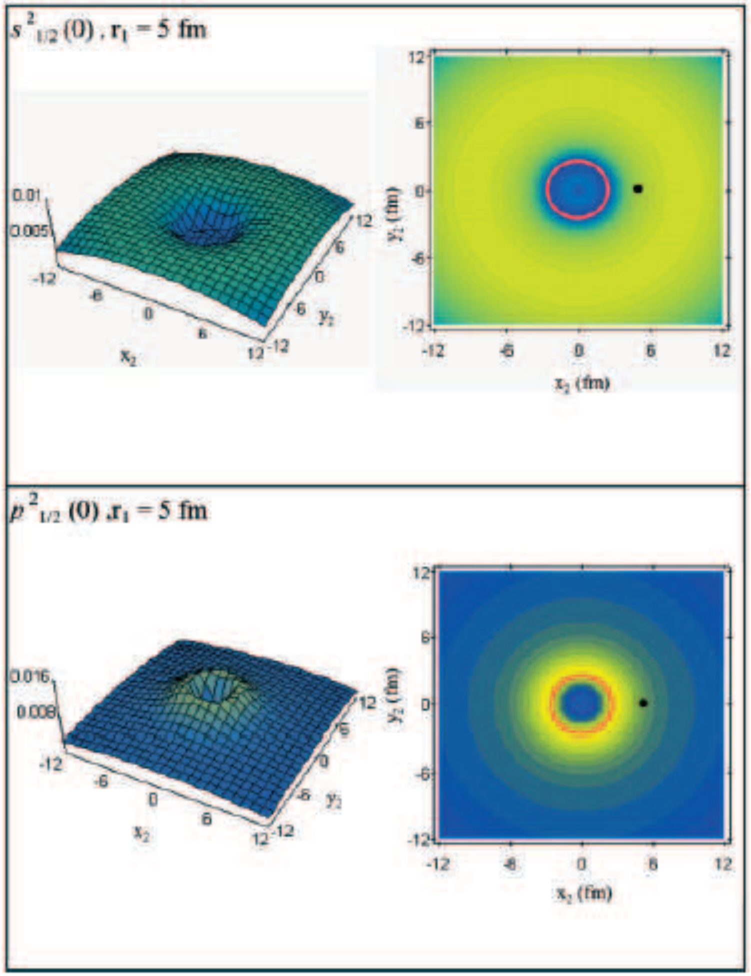
$$|\tilde{0}\rangle = |0\rangle + 0.7|(ps)_{1^-} \otimes 1^-; 0\rangle + 0.1|(sd)_{2^+} \otimes 2^+; 0\rangle$$

$$|0\rangle = 0.45|s^2_{1/2}(0)\rangle + 0.55|p^2_{1/2}(0)\rangle + 0.04|d^2_{5/2}(0)\rangle$$

Correlated halo wavefunction



Uncorrelated



^{11}Li correlated wave function

The halo wavefunction is made out of components which are superposition of single-particle wavefunctions in the discretized continuum, leading to a bound state:

$$|0\rangle = 0.45|s^2_{1/2}(0)\rangle + 0.55|p^2_{1/2}(0)\rangle + 0.04|d^2_{5/2}(0)\rangle$$

A part of the wavefunction is explicitly coupled to 1- and 2+ vibrations:

$$|\tilde{0}\rangle = |0\rangle + 0.7|(ps)_{1^-} \otimes 1^-; 0\rangle + 0.1|(sd)_{2^+} \otimes 2^+; 0\rangle$$

Probing ^{11}Li halo-neutrons correlations via (p,t) reaction

PRL **100,** 192502 (2008) PHYSICAL REVIEW LETTERS week ending 16 MAY 200

Measurement of the Two-Halo Neutron Transfer Reaction $^{1}H(^{11}Li, ^{9}Li)^{3}H$ at 3A MeV

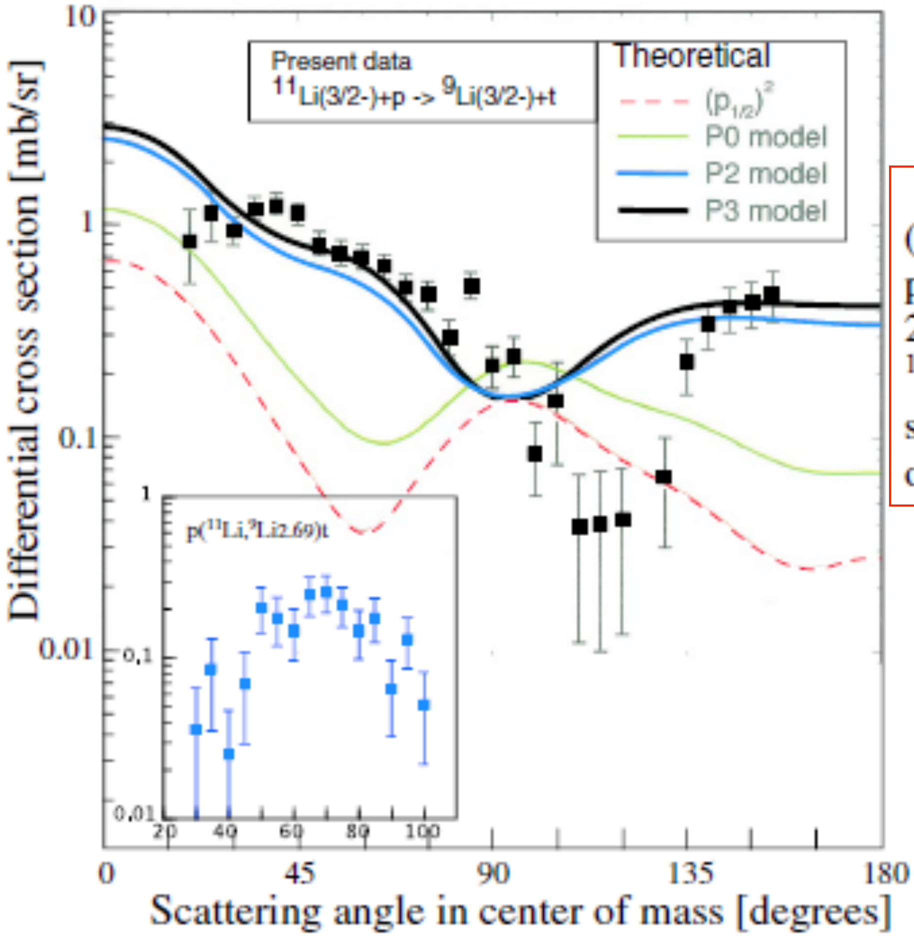
I. Tanihata,* M. Alcorta,† D. Bandyopadhyay, R. Bieri, L. Buchmann, B. Davids, N. Galinski, D. Howell, W. Mills, S. Mythili, R. Openshaw, E. Padilla-Rodal, G. Ruprecht, G. Sheffer, A. C. Shotter, M. Trinczek, and P. Walden
TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, V6T 2A3, Canada

H. Savajols, T. Roger, M. Caamano, W. Mittig,‡ and P. Roussel-Chomaz
GANIL, Bd Henri Becquerel, BP 55027, 14076 Caen Cedex 05, France

R. Kanungo and A. Gallant
Saint Mary's University, 923 Robie St., Halifax, Nova Scotia B3H 3C3, Canada

M. Notani and G. Savard
ANL, 9700 S. Cass Ave., Argonne, Illinois 60439, USA

I. J. Thompson
LLNL, L-414, P.O. Box 808, Livermore, California 94551, USA
(Received 22 January 2008; published 14 May 2008)



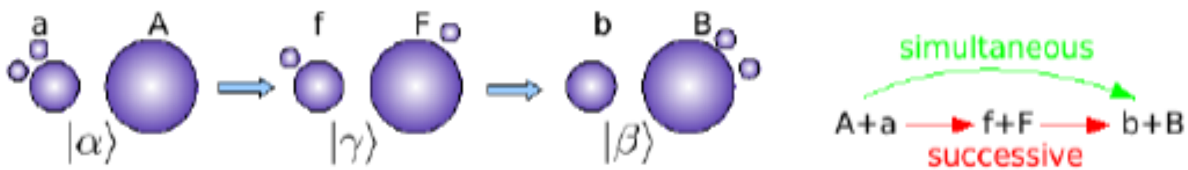
The cross section for transitions to the first excited state (Ex = 2.69 MeV) is shown also in Fig. 3. If this state were populated by a direct transfer, it would indicate that a 1^+ or 2^+ halo component is present in the ground state of ^{11}Li($\frac{3}{2}^-$), because the spin-parity of the ^{9}Li first excited state is $\frac{1}{2}^-$. This is new information that has not yet been observed in any of previous investigations. A compound

TABLE I. Optical potential parameters used for the present calculations.

	V MeV	r_V fm	a_V fm	W MeV	W_D MeV	r_W fm	a_W fm	V_{so} MeV	r_{so} fm	a_{so} fm
$p + {}^{11}$Li [10]	54.06	1.17	0.75	2.37	16.87	1.32	0.82	6.2	1.01	0.75
$d + {}^{10}$Li [11]	85.8	1.17	0.76	1.117	11.863	1.325	0.731	0		
$t + {}^{9}$Li [12]	1.42	1.16	0.78	28.2	0	1.88	0.61	0		

Calculation of absolute two-nucleon transfer cross section by finite-range DWBA calculation

simultaneous and successive contributions



the initial and final channel wave functions are

$$|\alpha\rangle = \phi_a(\xi_b, \mathbf{r}_1, \mathbf{r}_2)\phi_A(\xi_A)\chi_{aA}(\mathbf{r}_{aA})$$
$$|\beta\rangle = \phi_b(\xi_b)\phi_B(\xi_A, \mathbf{r}_1, \mathbf{r}_2)\chi_{bB}(\mathbf{r}_{bB})$$

very schematically, the first order (*simultaneous*) contribution is

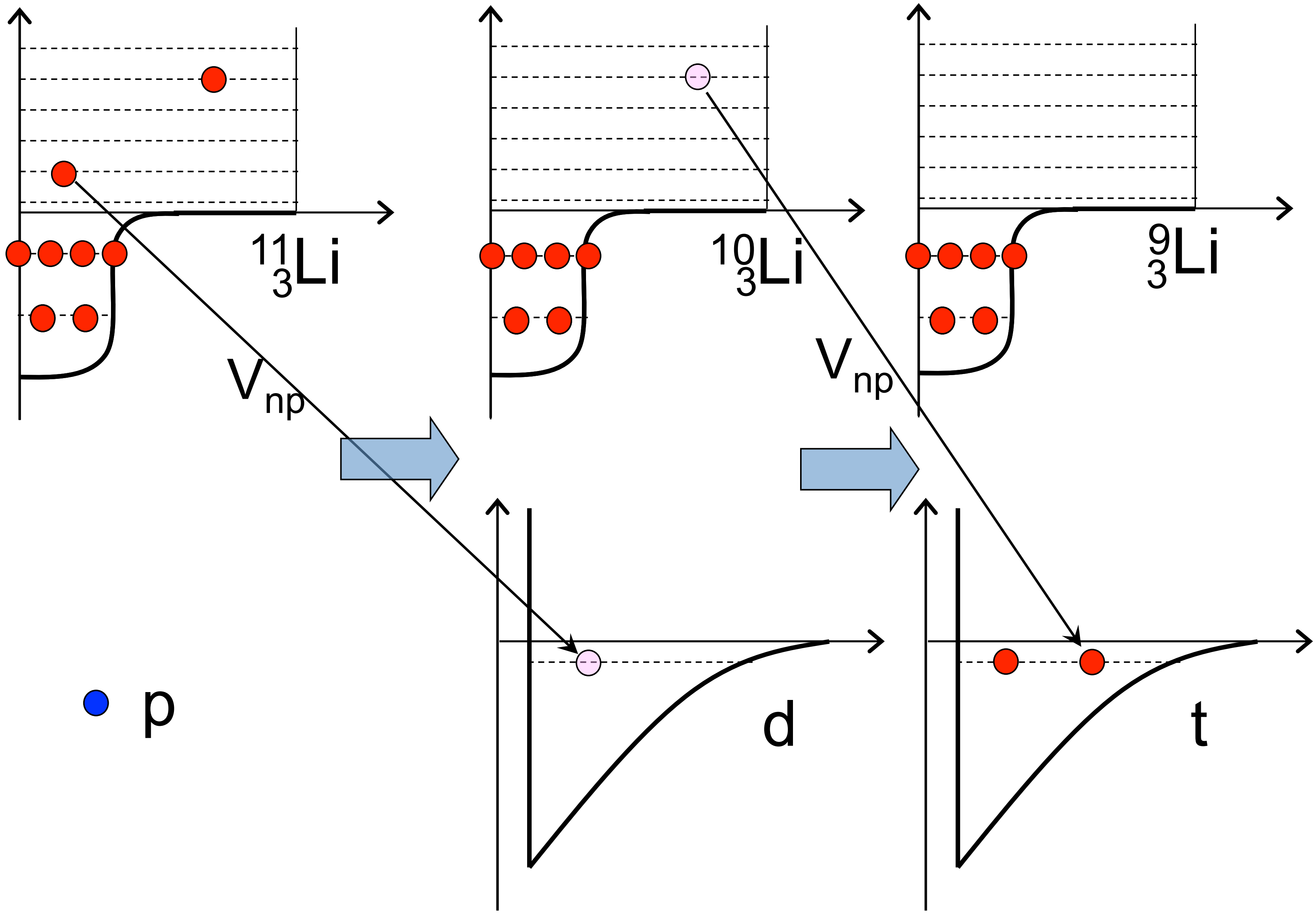
$$T^{(1)} = \langle\beta|V|\alpha\rangle,$$

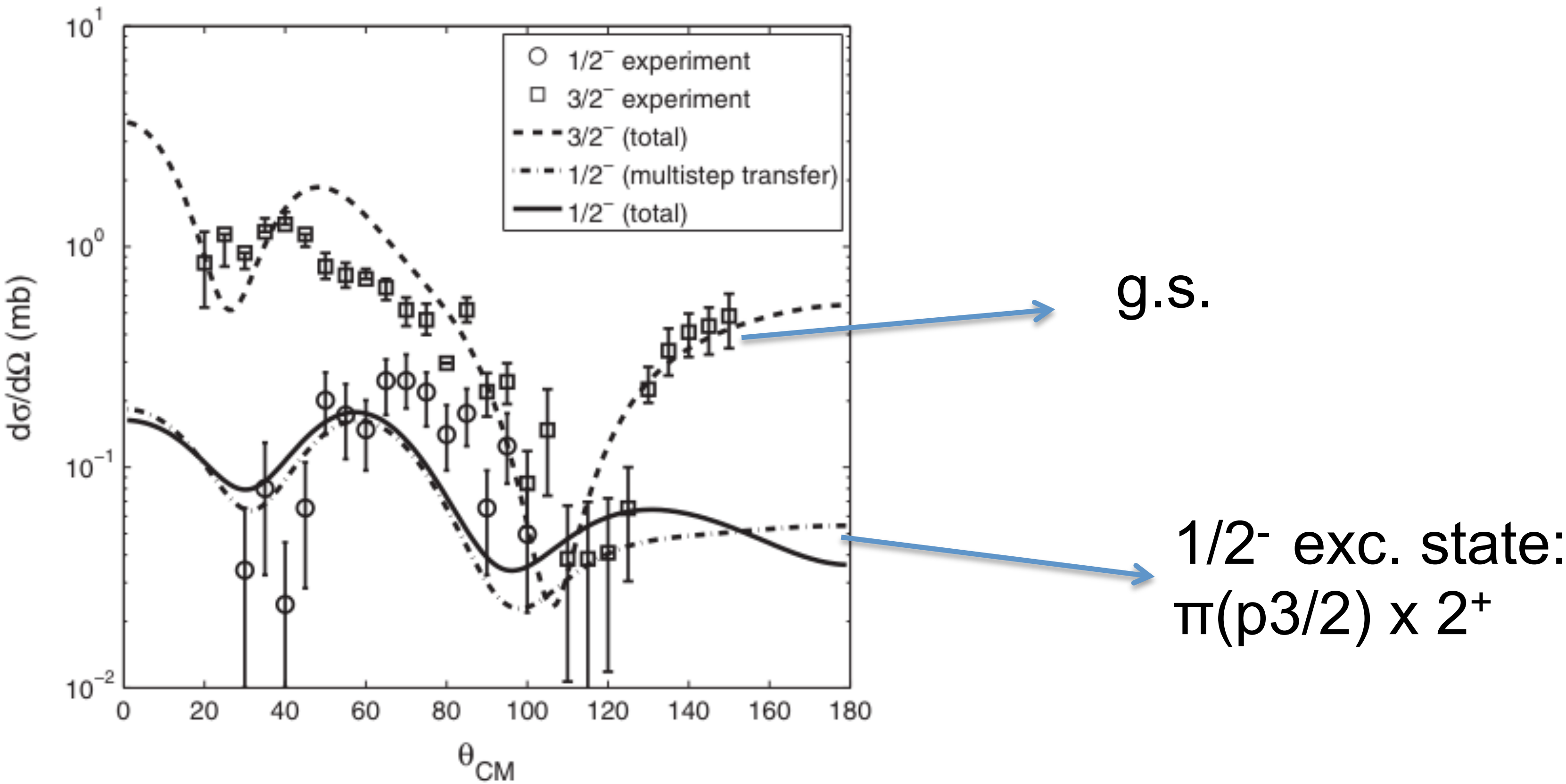
while the second order contribution can be separated in a *successive* and a *non-orthogonality* term

$$T^{(2)} = T^{(2)}_{succ} + T^{(2)}_{NO}$$
$$= \sum_\gamma \langle\beta|V|\gamma\rangle G\langle\gamma|V|\alpha\rangle - \sum_\gamma \langle\beta|\gamma\rangle\langle\gamma|V|\alpha\rangle.$$

B.F. Bayman and J. Chen, Phys. Rev. C 26 (1982) 150
M. Igarashi, K. Kubo and K. Yagi, Phys. Rep. 199 (1991) 1
G. Potel et al., arXiv: 0906.4298

$$\sum_{n_1,n_2} a_{n_1,n_2}[\psi_{n_1}(r_1)\psi_{n_2}(r_2)]_{00}$$



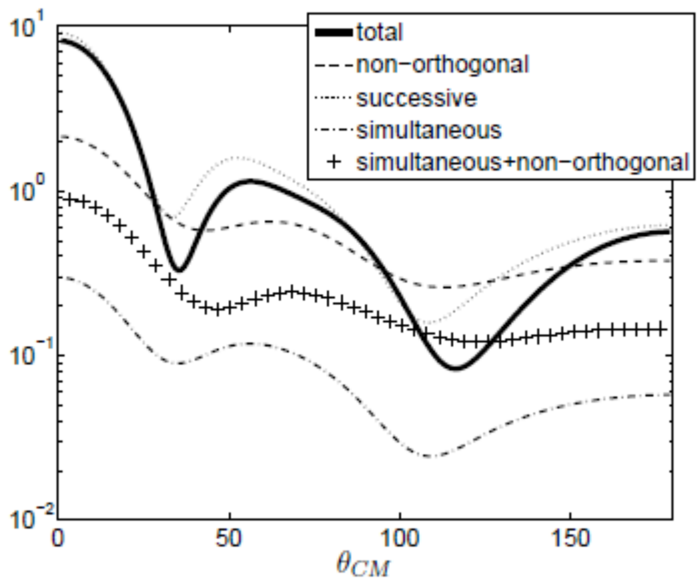


	$\sigma(^{11}\mathrm{Li(gs)} \to {}^{9}\mathrm{Li\ (i)})$ (mb)		
i	ΔL	Theory	Experiment
gs $(3/2^-)$	0	6.1	5.7 ± 0.9
2.69 MeV $(1/2^-)$	2	0.5	1.0 ± 0.36

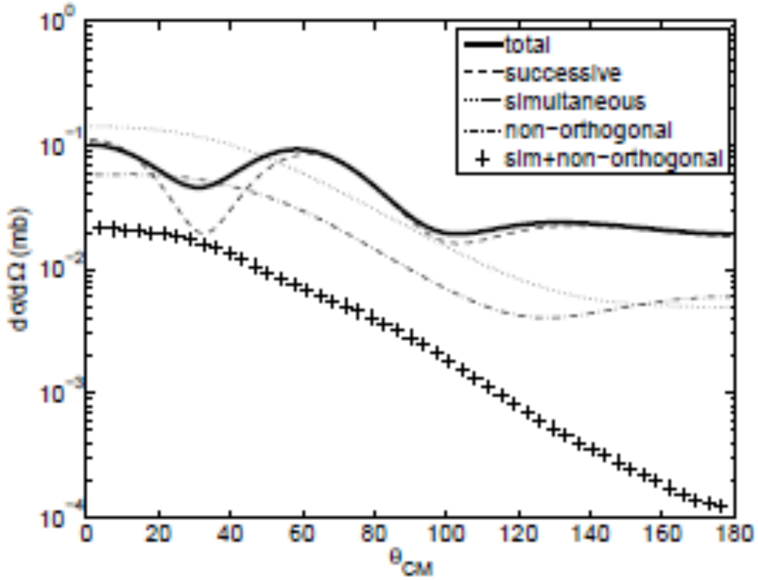
G. Potel et al., PRL 105 (2010) 172502

Decomposition into successive and simultaneous contributions

3/2- ground state

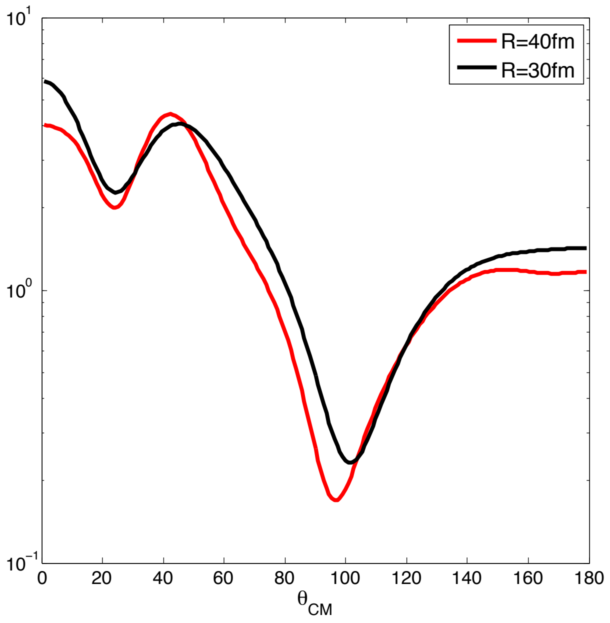


1/2- excited state

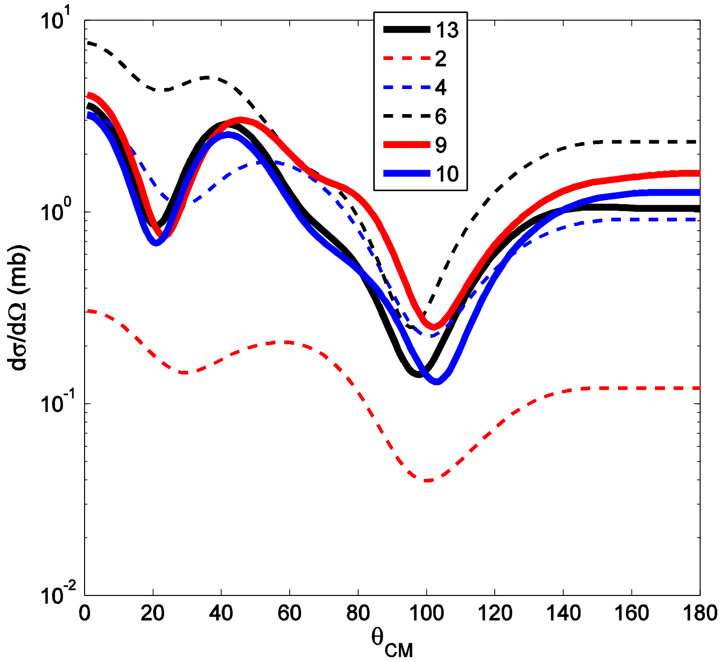


Convergence of the calculation

With box radius



With number of intermediate states

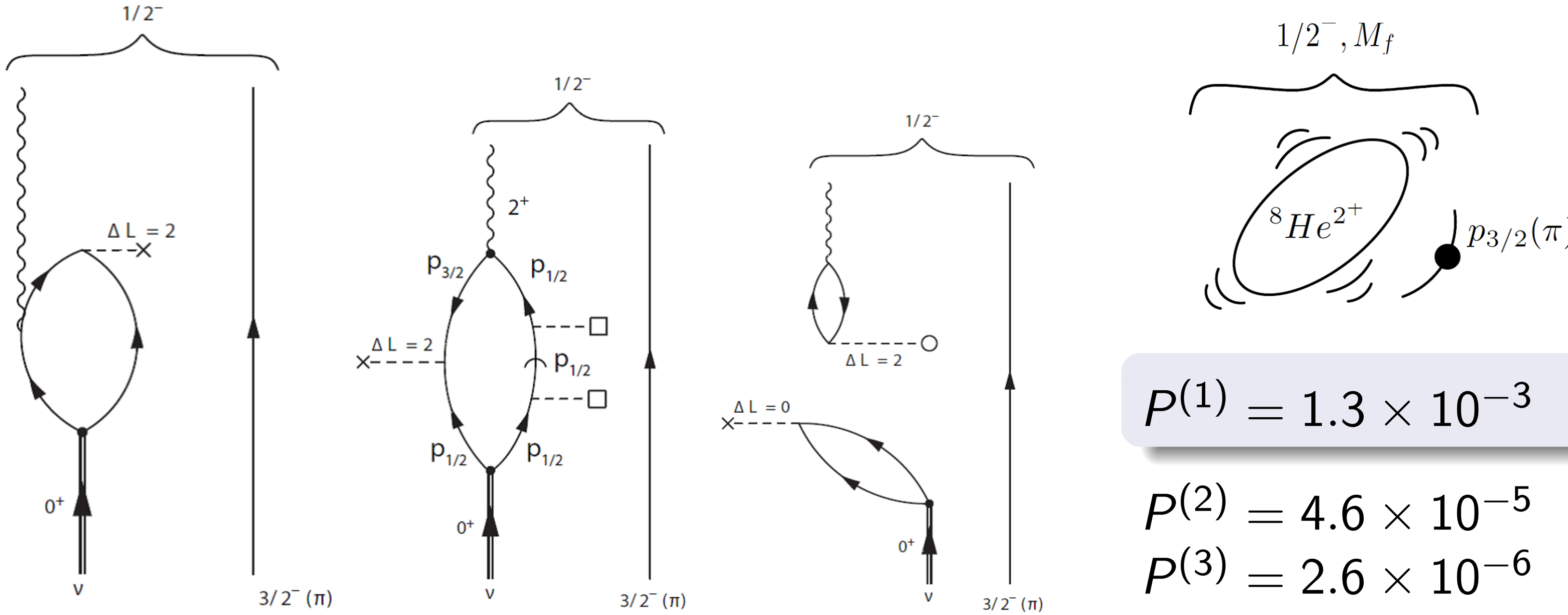


Channels c leading to the first $1/2^-$ excited state of ^{9}Li

$c = 1$: Transfer of the two halo neutrons

$c = 2$: Transfer of a $p_{1/2}$ halo neutron and a $p_{3/2}$ core neutron

$c = 3$: Transfer to the ground state + inelastic excitation



$P^{(1)} = 1.3 \times 10^{-3}$

$P^{(2)} = 4.6 \times 10^{-5}$

$P^{(3)} = 2.6 \times 10^{-6}$

$\sigma_c = \frac{\pi}{k^2} \sum_l (2l+1)|S_l^{(c)}|^2$, $P^{(c)} = \sum_l |S_l^{(c)}|^2$ $(c = 1, 2, 3)$.

Small probabilities $\Rightarrow$ use of second order perturbation theory.

Results for ^{11}Be,^{12}Be
Good agreement between theory and experiment concerning energies and spectroscopic factors

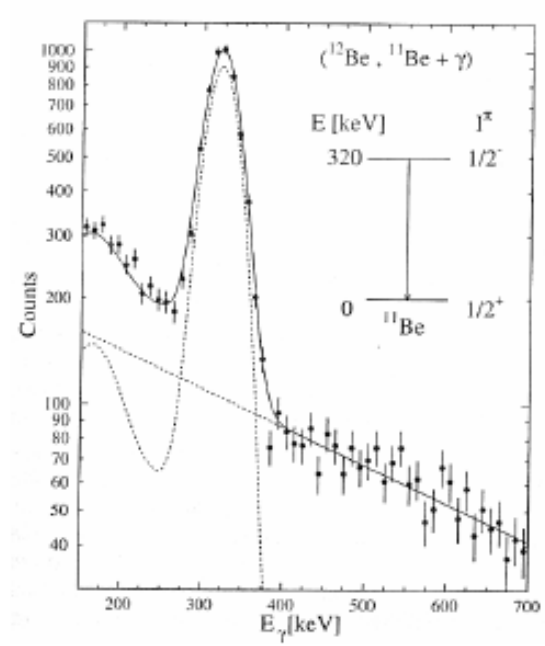
New result for S[1/2+]: $0.28^{+0.03}_{-0.07}$

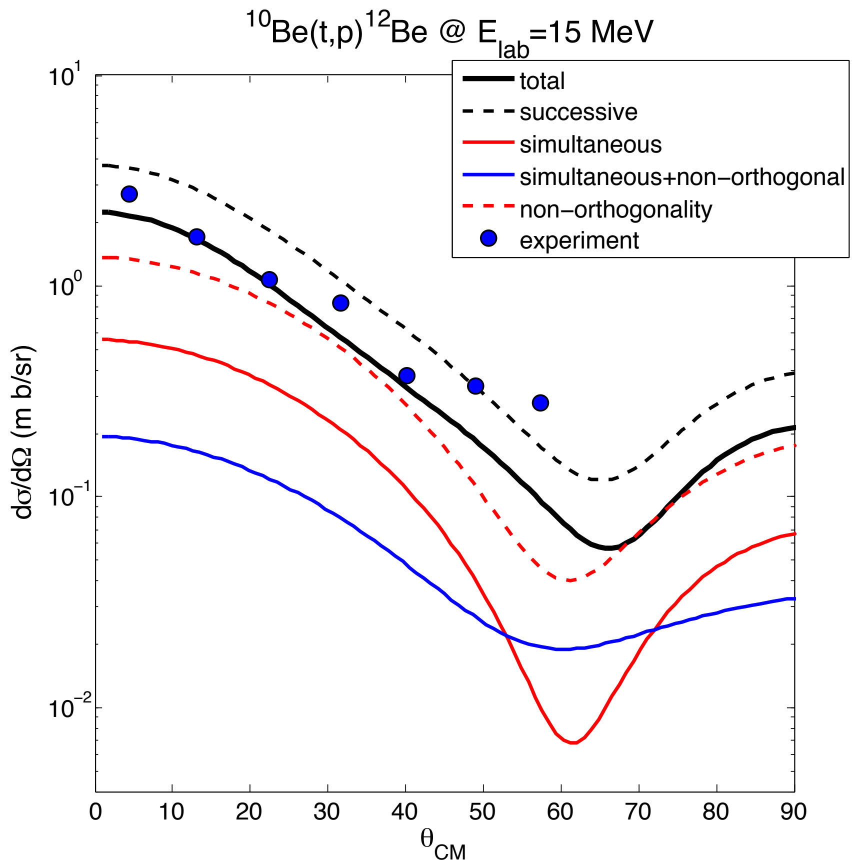
Kanungo et al.
PLB 682 (2010) 39

Spectroscopic factors from (12Be,11Be+γ) reaction to ½⁺ and ½- final states:
S[1/2-]= 0.37±0.10 S[1/2+]= 0.42±0.10

		Expt.	Theory: Particle vibration	Theory: Mean field
$^{11}_{4}Be_7$	$E_{s_{1/2}}$	−0.504 MeV	−0.48 MeV	~0.14 MeV
	$E_{p_{1/2}}$	−0.18 MeV	−0.27 MeV	−3.12 MeV
	$E_{d_{5/2}}$	1.28 MeV	~0 MeV	~2.4 MeV
	$S[1/2^+]$	0.65−0.80 [19]	0.87	1
		0.73±0.06 [20]		
		0.77 [21]		
	$S[1/2^-]$	0.63±0.15 [20]	0.96	1
		0.96 [21]		1
	$S[5/2^+]$		0.72	1
$^{12}_{4}Be_8$	S_{2n}	−3.673 MeV	−3.58 MeV	−6.24 MeV
	s^2,p^2,d^2		23%, 29%, 48%	0%, 100%, 0%
	$S[1/2^+]$	0.42±0.10 [7]	0.31	0
	$S[1/2^-]$	0.37±0.10 [7]	0.57	2

A. Navin et al.,
PRL 85(2000)266





^{10}Be(t,p) cross section to the g.s.state is well reproduced

Data:
H.T. Fortune, G.B. Liu, D.E. Alburger, Phys. Rev C50 (1994) 1355

Excited 0+ is not seen in (t,p)

H.T. Fortune and R. Sherr, PRC74(2006) 024301

TABLE III. Calculated and measured properties of first two 0^+ states in ^{12}Be.

Calc.	Ref.	State	Wave-function intensities			Splitting in ^{12}O (MeV)	Cross-section ratio	
			s^2	d^2	p shell		^{10}Be(t, p)	^{14}C(p, t)
	Present[a]	g.s.	0.53	0.15	0.32			
		$0^{+\prime}$	0.17	0.05	0.68	1.95	0.008	~0.5
	Barker[b]	g.s.	0.325	0.292	0.384			
		$0^{+\prime}$	0.67	0.10	0.23	1.19[c]	0.10[c]	~0.07[c]
Exp.						Unknown	Very small[d]	~0.3–0.5[e]

CONCLUSION:

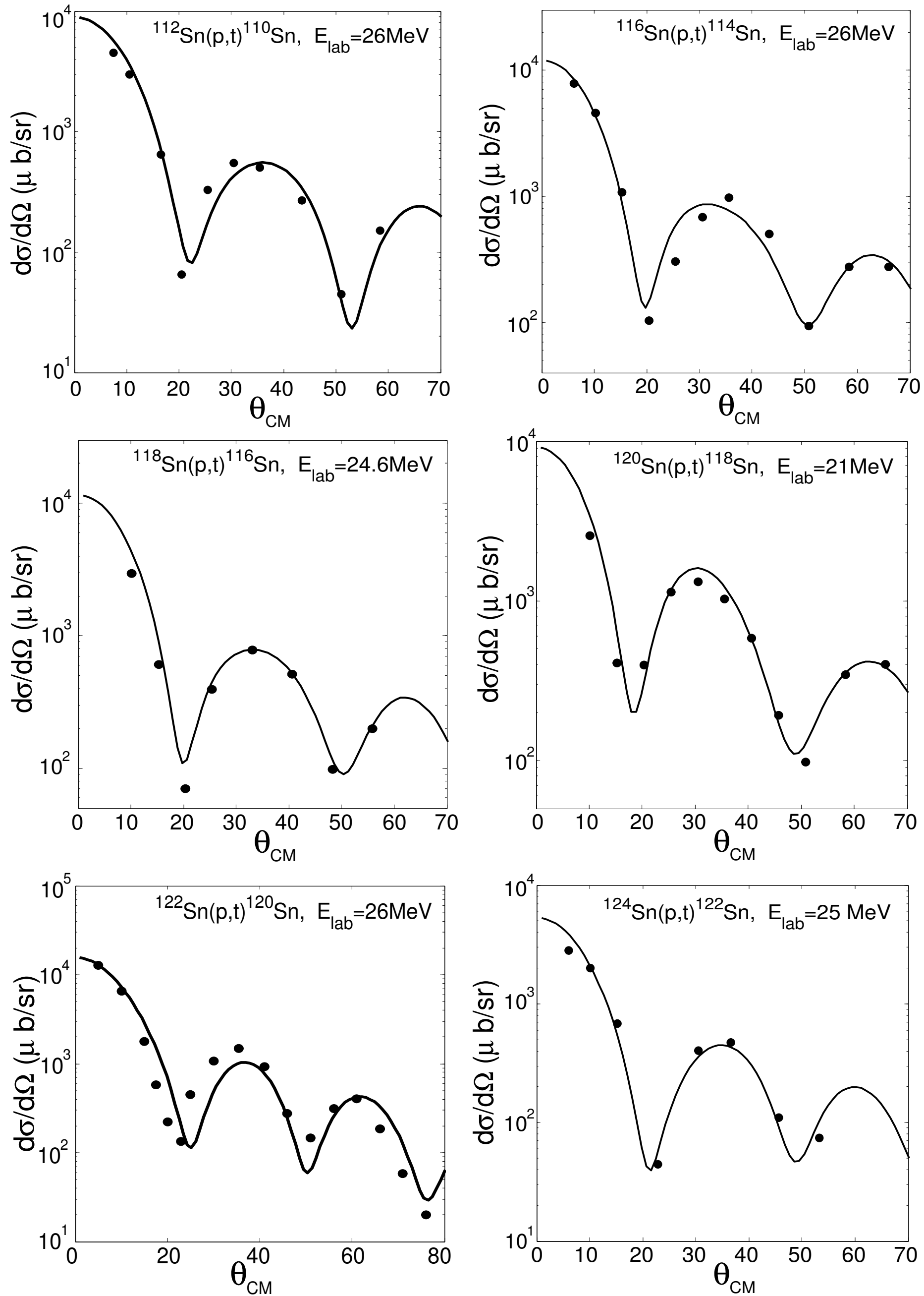
According to a dynamical model of the halo nucleus 11Li,
a key role is played by the coupling of the valence nucleons
with the vibrations of the system.
The structure model has been tested with a detailed reaction
calculation, comparing with data obtained in a recent (t,p) experiment.
Theoretical and experimental cross section are in reasonable agreement.

Many open issues, among them:

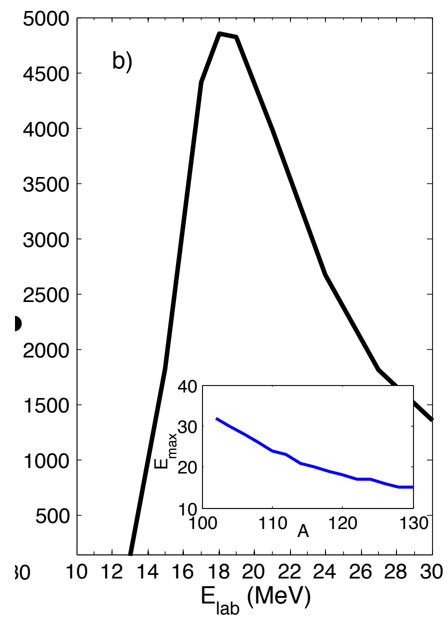
Optical potentials

The role of the tensor force

$^{A}Sn(p,t)^{A-2}Sn$, results



- BCS wavefunctions reproducing experimental pairing gaps
- Tang-Herndon wavefunctions for the triton
- Optical potential fitted by Guazzoni et al



G. Potel et al., PRL107 (2011) 092501

Some recent 2-nucleon transfer experiment

$t(^{30}Mg,^{32}Mg)p$	K. Wimmer et al. ,PRL 105 (2011) 252501
$p(^{11}Li, ^{9}Li)t$	I. Tanihata et al., PRL 100 (2008) 192502
$p(^{8}He,^{6}He)t$	N. Keeley et al., PLB 646 (2007) 222
$^{121}Sb(p,t)^{119}Sb$	P. Guazzoni et al., J.Phys.G 34 (2007)2665
$^{120}Sn(p,t)^{118}Sn$	P. Guazzoni et al., PRC 78 (2008)064608
$^{134}Ba(p,t)^{132}Ba$	S. Pascu et al., PRC 81 (2010)014304
$^{65}Cu(^{6}He ,^{4}He)^{67}Cu$	A. Chatterjee et al., PRL 101 (2008) 032701
$^{9}Be (^{18}O,^{16}O)^{11}Be$	M. Cavallaro et al., J. Phys G Conf. Ser. 312(2011)092020
$^{40}Ca(^{96}Zr,^{94}Zr)^{42}Ca$	L. Corradi et al. , PRC 84(2011)034603

EFFECT	REACTION Energy	LISE area Experimental conditions set-up
Nuclear shape evolution in Ge and shape coexistence by identifying a possible low-lying excited 0^+_2 state, and measuring its excitation energy	^{68}Ge(p,t) ^{66}Ge 33MeV/n	4 MUST2 + BTD + 4 Exogam clovers
Shell evolution at Z=14, N=8 Populate the 0+ and 2+ states in ^{22}Si	^{24}Si(p,t) ^{22}Si 42 MeV/n	5 MUST2 + BTD + Solid H_2 target
Pair transfer to investigate the neutron-proton pairing in the f7/2 shell	^{48}Cr(p,^{3}He) (d,^{4}He) ^{56}Ni(p,^{3}He) (d,^{4}He) 30 MeV/n	4 MUST2 + BTD + TIARA + 4 Exogam clovers

- t(^{44}Ar,^{46}Ar)p: deformation and shape coexistence, 2010, K. Nowak et al. (TU München
- t(^{66}Ni,^{68}Ni)p: study the $N = 40$ nucleus ^{68}Ni, 2011, T.Roger et al. (KU Leuven
- t(^{72}Zn,^{74}Zn)p: transfer and Coulomb excitation, 2011, D. Mücher et al. (TU München