INFN Istituto Nazionale di Fisica Nucleare
SEZIONE DI PISA
Angela Bonaccorso

L.E.A. COLLIGA — Laboratoire Européen Associé - Laboratorio Europeo Associato

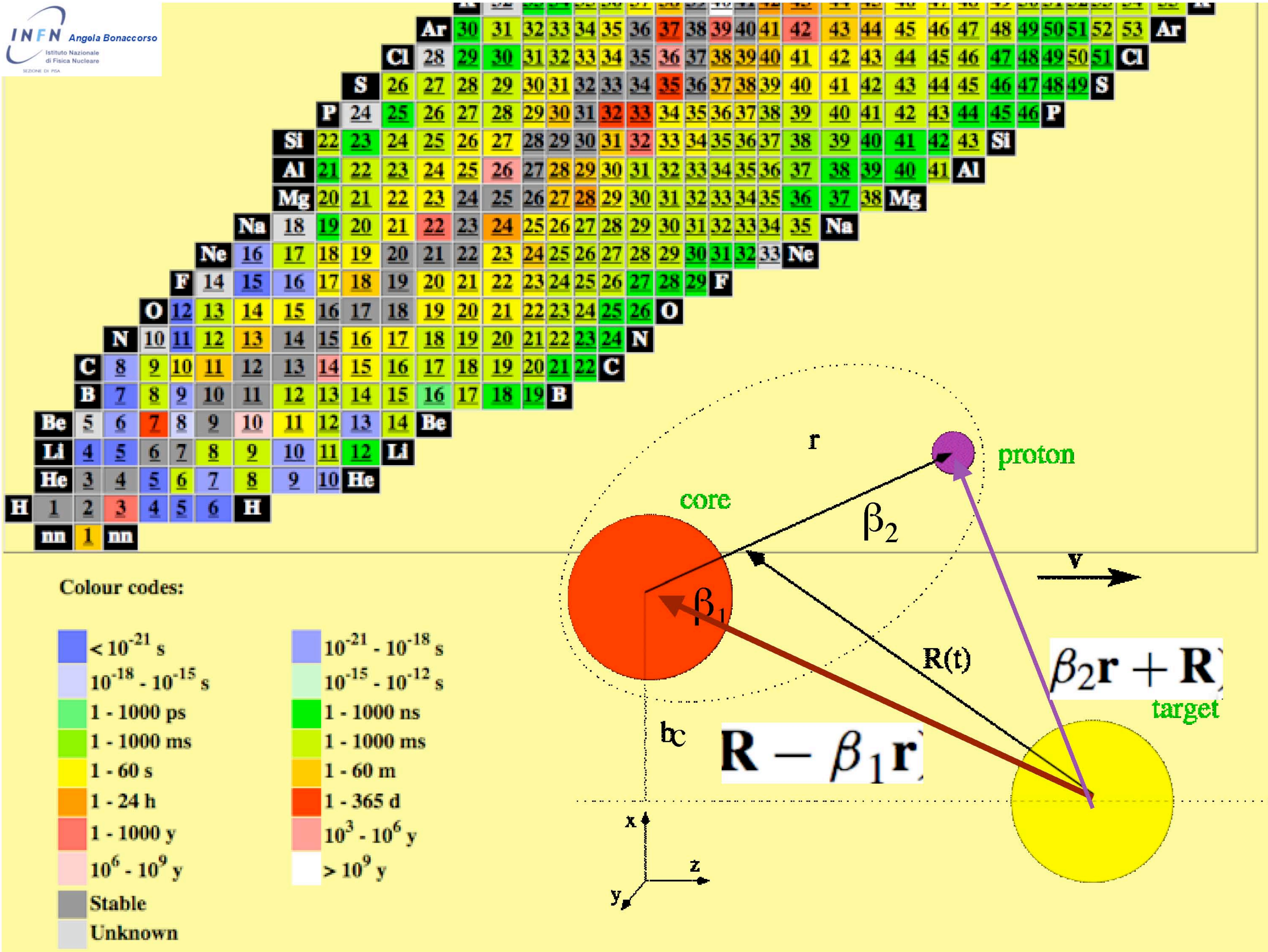
Direct Reactions with Spectrometers

G. Blanchon, C. A. Bertulani, D.M. Brink, F. Carstoiu, A. Garcia-Camacho, R. Kumar, J.Margueron, N. Vinh Mau

F. Cappuzzello, M. Cavallaro, A. Cunsolo et al.

IV French-Italian meeting of the Associate European Laboratory (LEA-COLLIGA)

INFN Laboratori Nazionali di Legnaro
18-19 November 2010



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Colour codes:
< 10^-21 s
10^-21 - 10^-18 s
10^-18 - 10^-15 s
10^-15 - 10^-12 s
1 - 1000 ps
1 - 1000 ns
1 - 1000 ms
1 - 1000 ms
1 - 60 s
1 - 60 m
1 - 24 h
1 - 365 d
1 - 1000 y
10^3 - 10^6 y
10^6 - 10^9 y
> 10^9 y
Stable
Unknown
r
proton
core
β2
v
β1
R(t)
β2r + R
target
bc
R − β1r
x
z
y

http://www.eurisol.org/usergroup/

EURISOL User Group

2nd Topical Meeting, Valencia, Spain

Neutron deficient exotic nuclei and the Physics of the "proton rich side" of the nuclear chart

21-23 February 2011 | Colegio Rector Peset

Main organizer: Berta Rubio rubio@ific.uv.es

FUTURE:

EURISOL NET

Physics & Instrumentation

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Astrophysical motivations to study neutron deficient nuclei

$^{8}B(p, \gamma)$ and flux from the Sun.

^{17}F plays an important role in understanding explosive nucleo-synthesis in X-ray bursts and novae, as it enters in the sequence $^{14}O(\alpha,p)\ ^{17}F(p, \gamma)^{18}Ne(\alpha,p)^{21}Na$, where cross sections are poorly known.

^{22}Na puzzle: reaction path ⟶ $^{20}Ne(p, \gamma)\ ^{21}Na(p, \gamma)\ ^{22}Mg(\beta^{+}, \nu)^{22}Na$.
γ -ray line of 1.275 keV not observed yet by telescopes COMPTEL or INTEGRAL following β^{+}-decay to ^{22}Ne from novae.
Alternative path $^{22}Na(p, \gamma)^{23}Mg$ and $^{22}Mg(p, \gamma)^{23}Al$.

Future RIKEN experiment (proposed by Texas AM group)
^{9}C at 100 A.MeV on ^{9}Be and ^{208}Pb targets and ^{9}C at 300 A.MeV on Pb.

Understand proton vs neutron reaction mechanism:
Does proton halo exist? Present data provide conflicting interpretations

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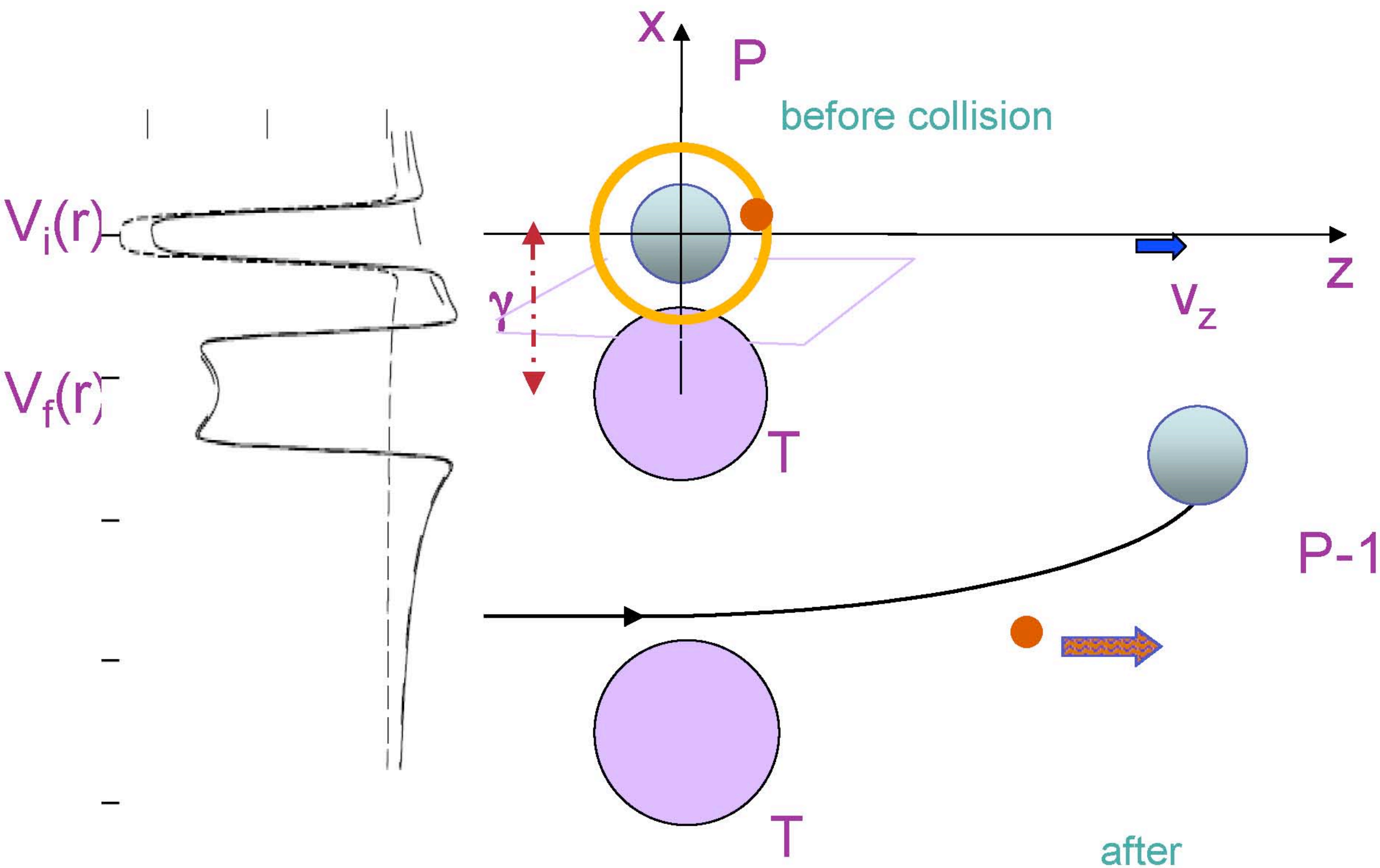
Neutron Coulomb Breakup : core recoil



R. Anne, et al., Nucl. Phys. A 575 (1994) 125.

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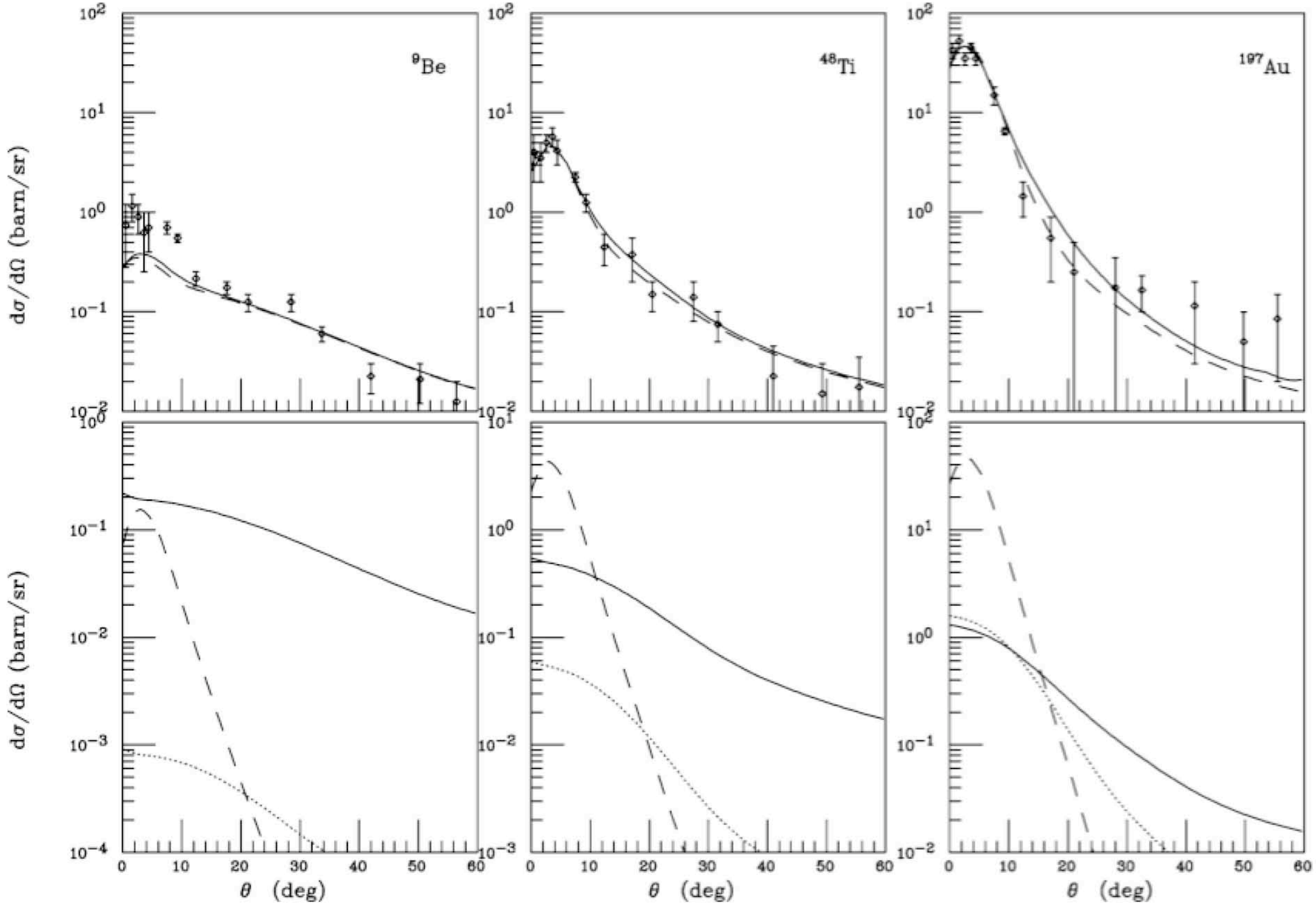

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ELSEVIER
Nuclear Physics A 703 (2002) 105–129
NUCLEAR PHYSICS A
www.elsevier.com/locate/npe

Coulomb-nuclear coupling and interference effects in the breakup of halo nuclei

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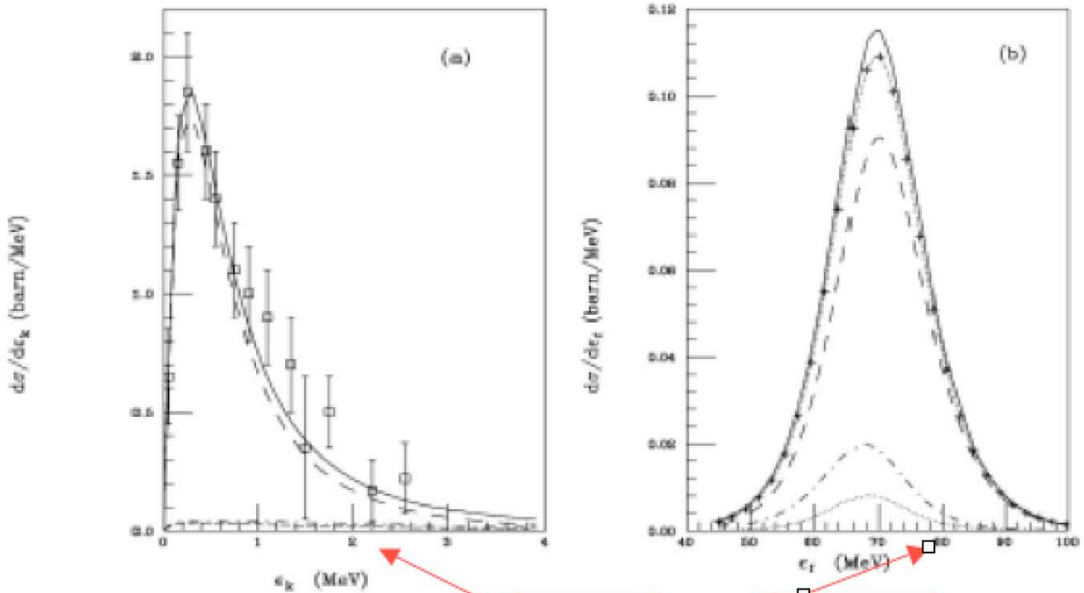
[b] Istituto Nazionale di Fisica Nucleare, Sezione di Pisa, 56100 Pisa, Italy
[c] Department of Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, UK



^{208}Pb target

energy spectra n-core and n-target

T. Nakamura et al.data from RIKEN

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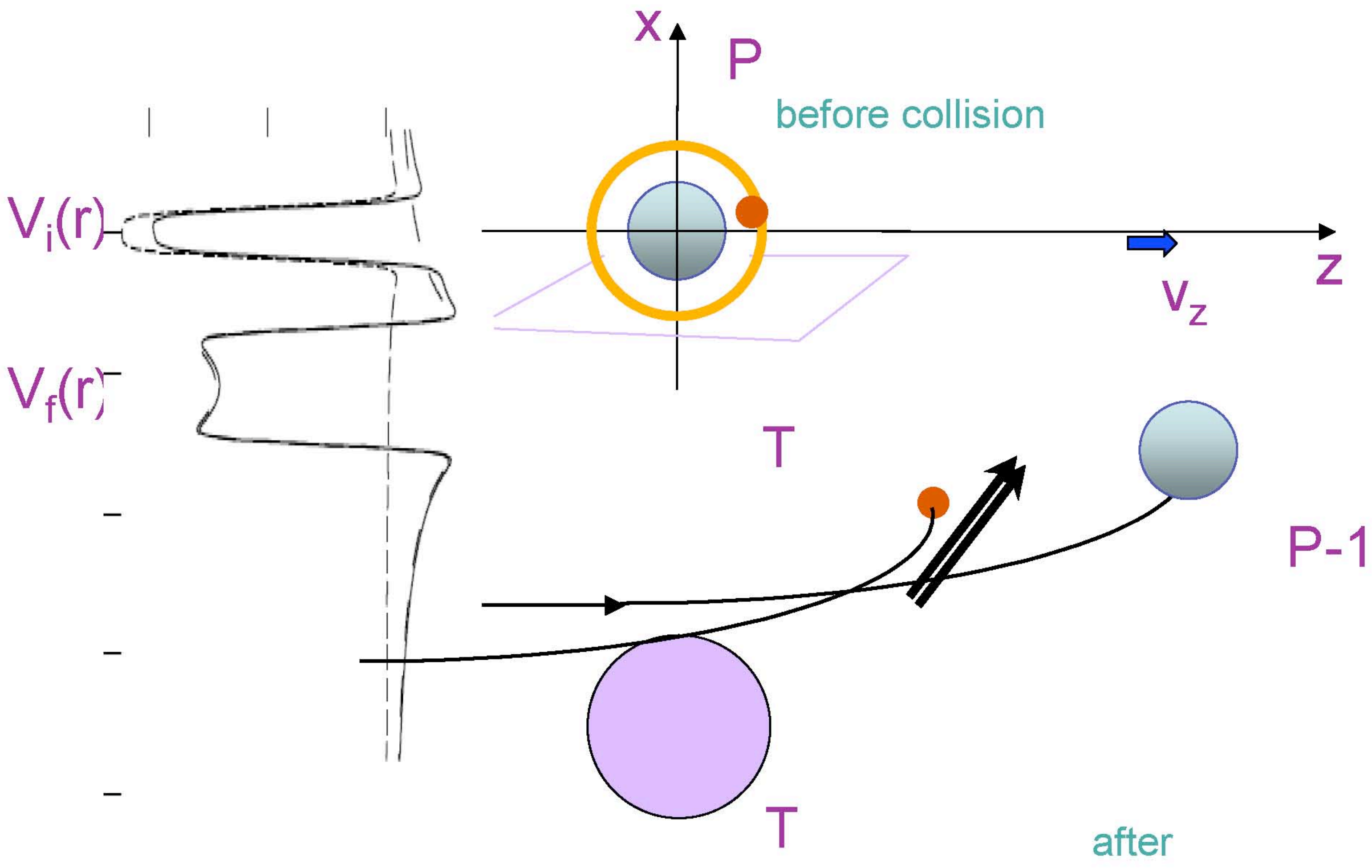
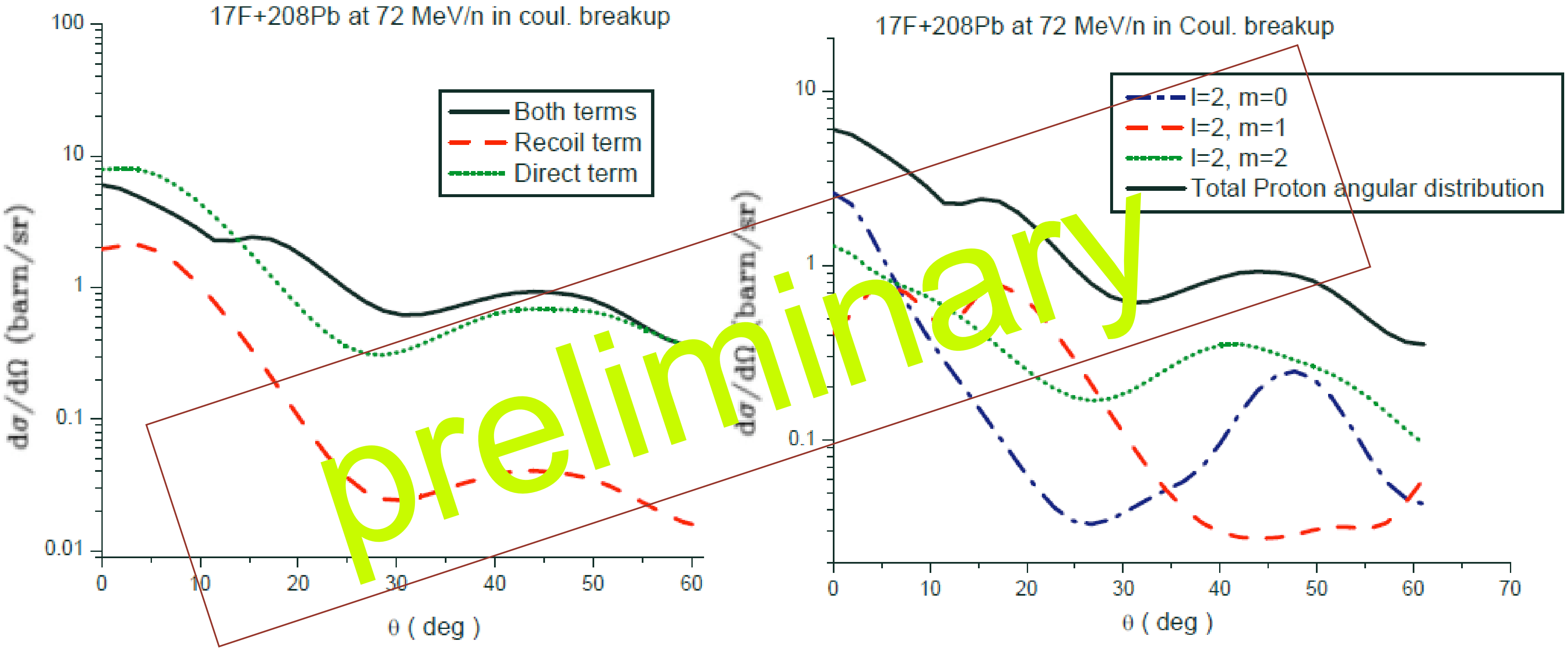
Proton Coulomb Breakup : core recoil + direct term



R. Kumar & AB, in preparation



A new very clear observable: inclusive proton angular distribution

PHYSICAL REVIEW C **76**, 014607 (2007)

All orders proton breakup from exotic nuclei

A. García-Camacho,[1] G. Blanchon,[1] A. Bonaccorso,[1] and D. M. Brink[2]
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[2]*Department of Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, United Kingdom*
(Received 12 February 2007; published 11 July 2007)

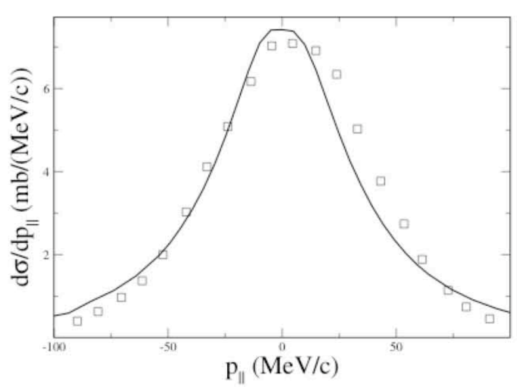


Figure 2: Calculated inclusive momentum distribution of ^{7}Be fragments afte proton-removal from ^{8}B against Pb at 936 MeV/A. Data are from [46].

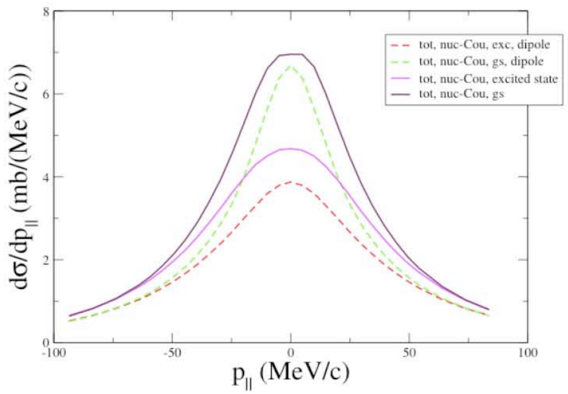


Figure 4: For the same reaction of Fig 2, proton momentum distribution in both dipole and full-multipole approximations, for both ground and excited state.

8] D. Cortina-Gil et al., Nucl. Phys. **A720** (2003) :

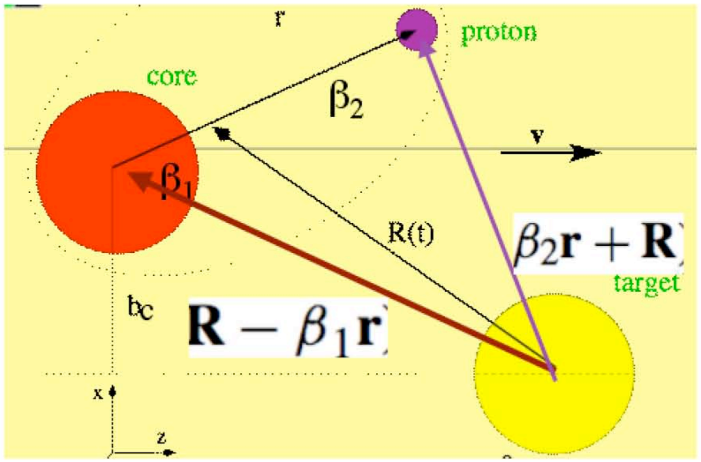
$$V(\vec{r},\vec{R}) = \frac{V_c}{|\vec{R}-\beta_1\vec{r}|} + \frac{V_v}{|\vec{R}+\beta_2\vec{r}|} - \frac{V_0}{R} \qquad (1)$$

where $V_c = Z_c Z_t e^2$, $V_v = Z_v Z_t e^2$ and $V_0 = (Z_v + Z_c) Z_t e^2$. β_1 and β_2 are the mass ratios of proton and core, respectively, to that of the projectile. The coordi-

Nuclear Physics A 720 (2003) 337–353

A non-perturbative approach to halo breakup

J. Margueron [a,b], A. Bonaccorso [a,*], D.M. Brink [c]



PHYSICAL REVIEW C 76, 014607 (2007)

All orders proton breakup from exotic nuclei

A. García-Camacho,[1] G. Blanchon,[1] A. Bonaccorso,[1] and D. M. Brink[2]

Our expression for the differential cross-section is

$$\frac{d\sigma}{d\vec{k}} = \frac{1}{8\pi^3}\int d\vec{b}_c |S_{ct}(b_c)|^2 |g^{rec} + g^{dir} + g^{nuc}|^2. \qquad (6)$$

where $S_{ct}(b_c)|^2$ is the core-target elastic scattering probability discussed later and the probability amplitude has been written as the sum of three pieces: the recoil term,

$$g^{rec} = \int d\vec{r} e^{-i\vec{k}\cdot\vec{r}}\phi_i(\vec{r})(e^{i\frac{2V_c}{\hbar v}\log\frac{b_c}{R_\perp}} - 1 - i\frac{2V_c}{\hbar v}\log\frac{b_c}{R_\perp} + i\chi(\beta_1, V_c)), \qquad (7)$$

where, according to the discussions in [1, 25, 26, 27], the sudden limit has been used in order to include all orders in the interaction. Similarly, the second term in our probability amplitude is the direct proton Coulomb interaction. It has the same form as Eq.(7) but for the substitution $V_c \to V_v$, $b_c \to b_v$ and $\beta_1 \to -\beta_2$.

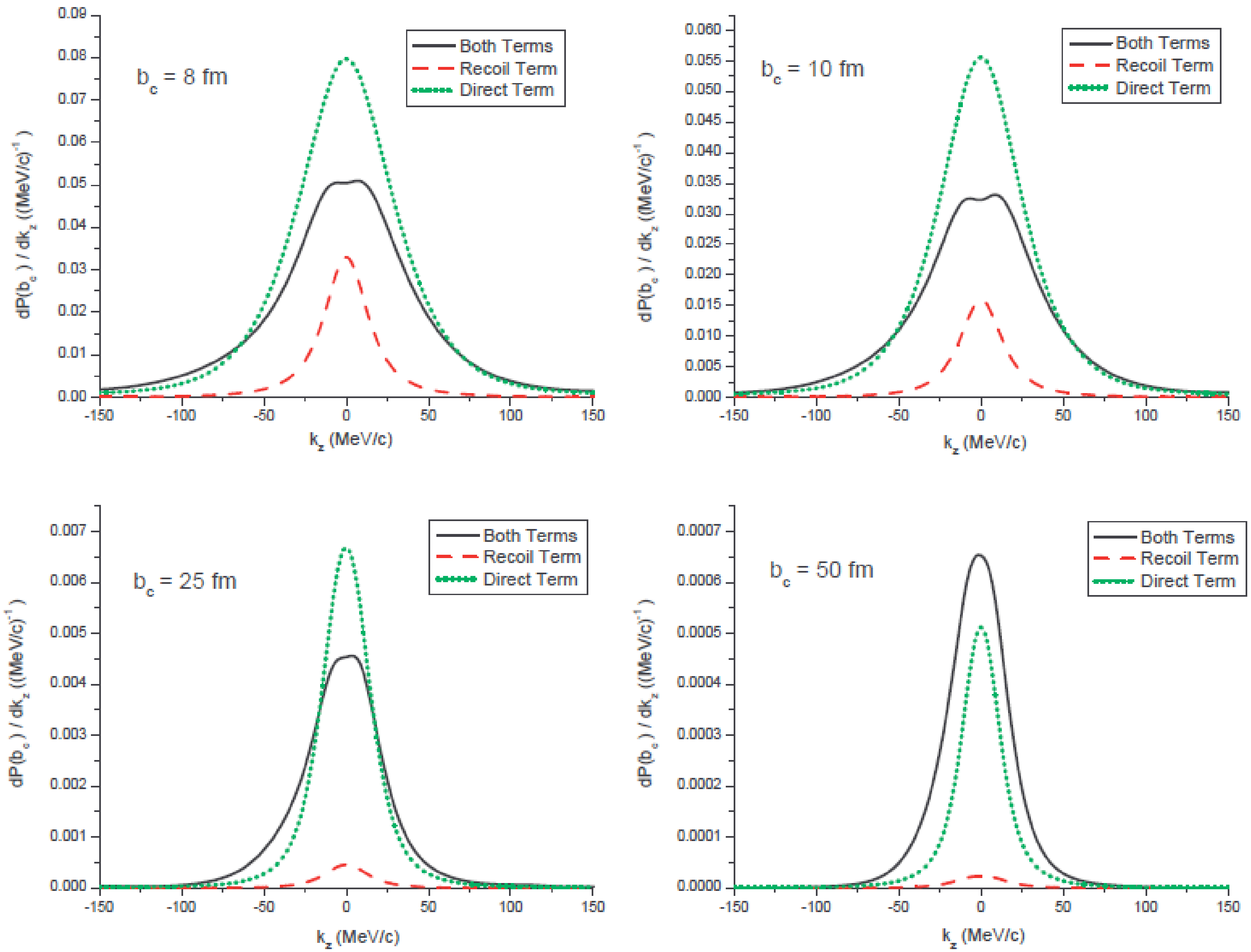
Finally, the nuclear part is

$$g^{nuc} = \int d\vec{r} e^{-i\vec{k}\cdot\vec{r}}\phi_i(\vec{r})\left(e^{i\chi_{nt}(b_v)} - 1\right). \qquad (8)$$

R. Kumar & AB, in preparation

8B+208Pb at 72 MeV/n (g.s.=$p_{3/2}$)

Coul. Breakup Prob. to All Order



The proton vs neutron case.

BONACCORSO, BRINK, AND BERTULANI PHYSICAL REVIEW C **69**, 024615 (2004)

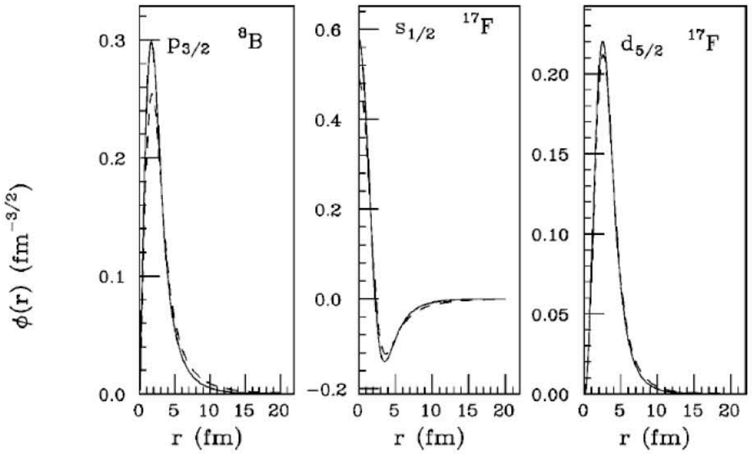


FIG. 3. Proton (dashed) and neutron (solid) wave functions for ^{8}B, ^{17}F as indicated. Neutron wave functions obtained for effective energies as in Table II, in the case of the ^{58}Ni target.

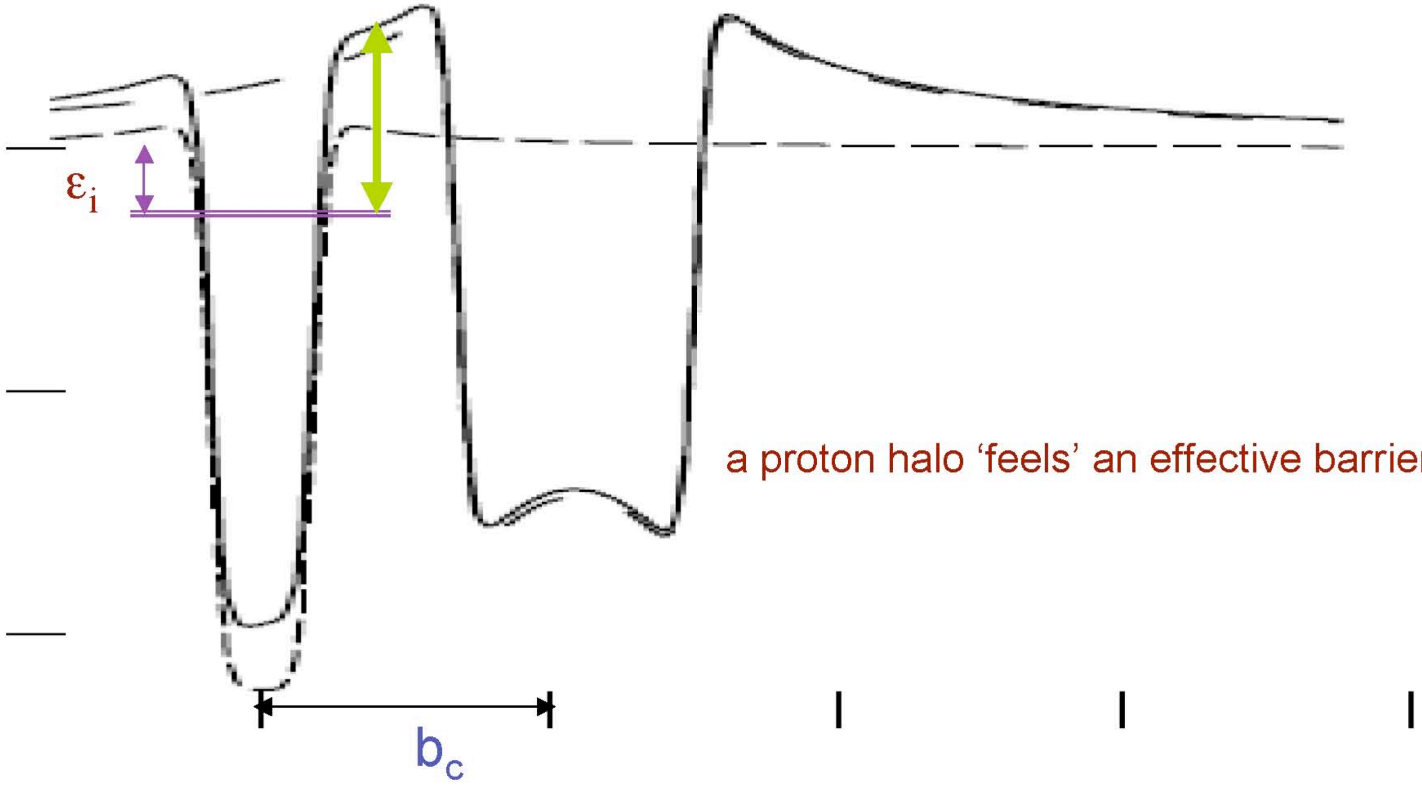
	^{8}B	J^π	^{17}F	J^π
$R_i(fm)$	6.0		6.5	
$\varepsilon_i(MeV)$	-0.14	$1p_{3/2}$	-0.6	$1d_{5/2}$
$\varepsilon_i^*(MeV)$	-0.57	$1p_{1/2}$	-0.1	$2s_{1/2}$

TABLE II. Effective parameters.

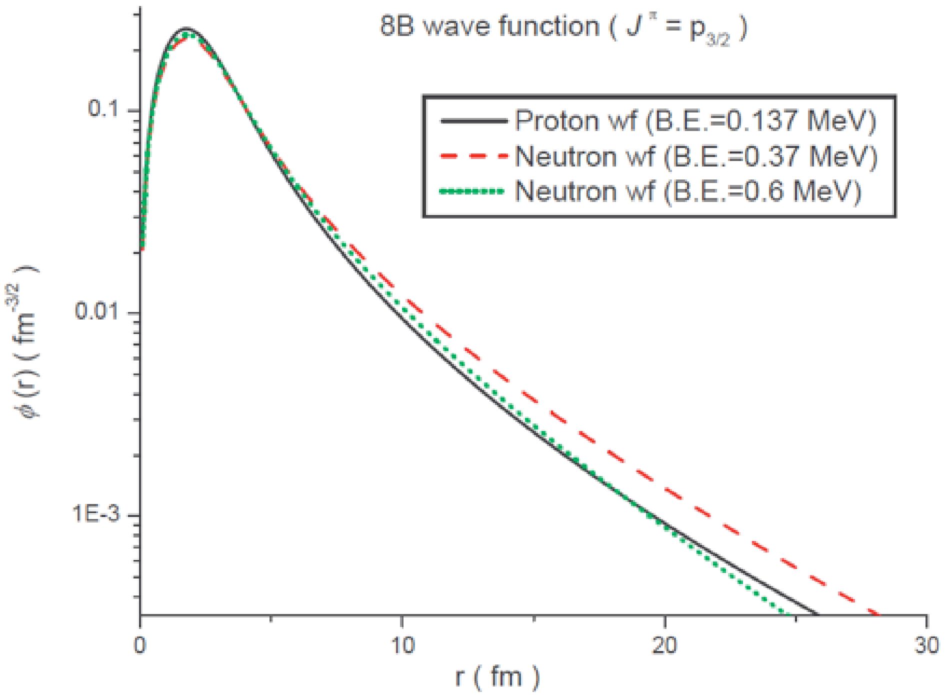
	^{8}B + ^{58}Ni	^{8}B + ^{208}Pb	^{17}F + ^{58}Ni	^{17}F + ^{208}Pb
Δ_i (MeV)	−1.85	−2.29	−2.7	−3.2
$\tilde{\varepsilon}_i$ (MeV)	−1.99	−2.43	−3.3	−3.8
$\tilde{\gamma}_i$ (fm^{-1})	0.29	0.34	0.39	0.42
$\tilde{C}_i$ (fm$^{-1/2}$)	0.69	0.79	0.75	0.89
$\tilde{\varepsilon}_i^*$ (MeV)			−2.8	−3.3
$\tilde{\gamma}_i^*$ (fm^{-1})			0.36	0.39
$\tilde{C}_i^*$ (fm$^{-1/2}$)			3.06	3.5

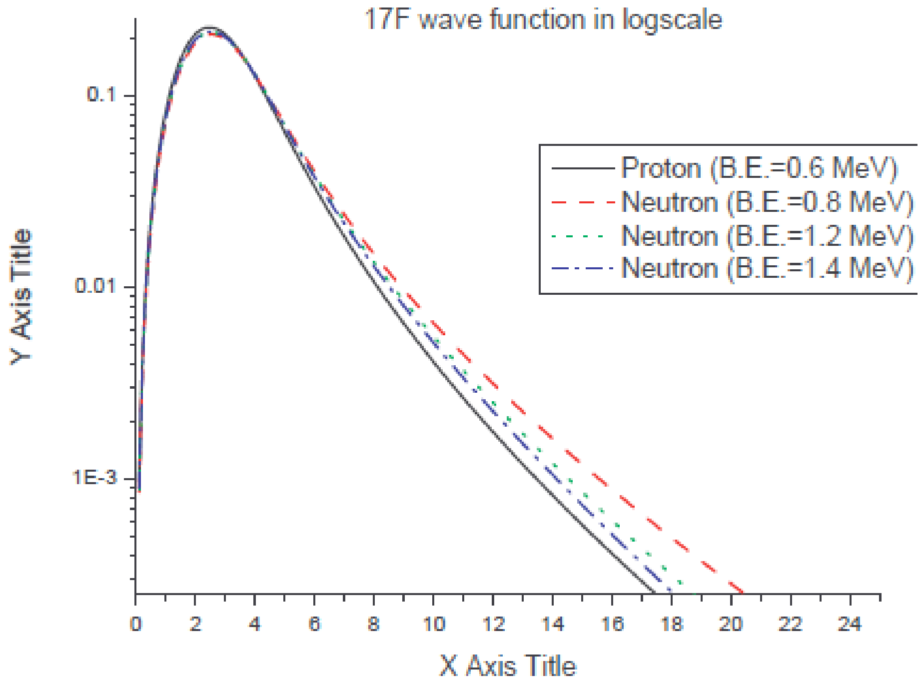
Δ

$$\tilde{\varepsilon}_i = \varepsilon_i - \frac{Z_p e^2}{R_i} - Z_t e^2 \left(\frac{1}{2} \left(\frac{1}{|b_c + R_i|} + \frac{1}{|b_c - R_i|} \right) - \frac{1}{b_c} \right)$$



a proton halo ‘feels’ an effective barrier


8B wave function (J^π = p_3/2)
Proton wf (B.E.=0.137 MeV)
Neutron wf (B.E.=0.37 MeV)
Neutron wf (B.E.=0.6 MeV)
φ (r) (fm^-3/2)
0.1
0.01
1E-3
0
10
20
30
r (fm)


17F wave function in logscale
Proton (B.E.=0.6 MeV)
Neutron (B.E.=0.8 MeV)
Neutron (B.E.=1.2 MeV)
Neutron (B.E.=1.4 MeV)
Y Axis Title
0.1
0.01
1E-3
0
2
4
6
8
10
12
14
16
18
20
22
24
X Axis Title

Physics Letters B 681 (2009) 22–25

Dynamic polarization in the Coulomb breakup of loosely bound ^{17}F

J.F. Liang [a,*], J.R. Beene [a], A.L. Caraley [b], H. Esbensen [c], A. Galindo-Uribarri [a], C.J. Gross [a], P.E. Mueller [a], K.T. Schmitt [d], D. Shapira [a], D.W. Stracener [a], R.L. Varner [a]

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[d] Department of Physics and Astronomy, University of Tennessee, Knoxville, TN 37966, USA

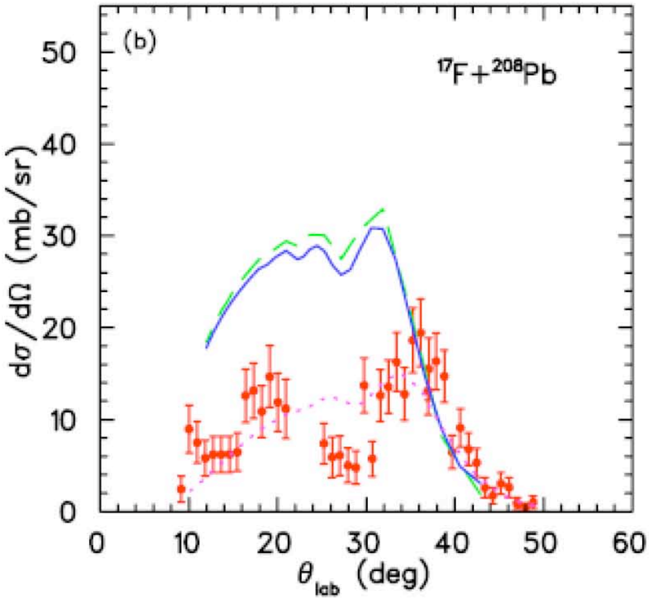
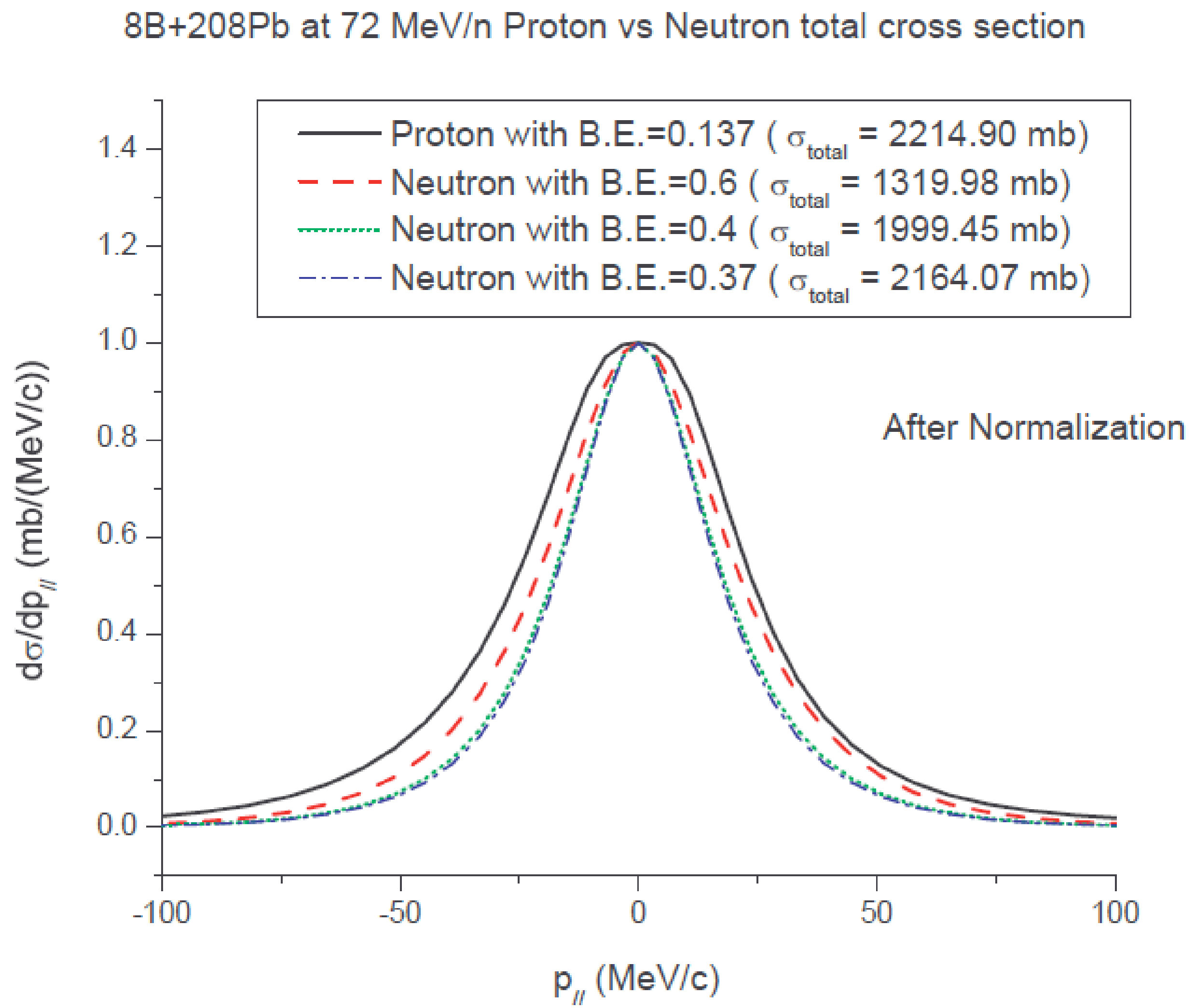
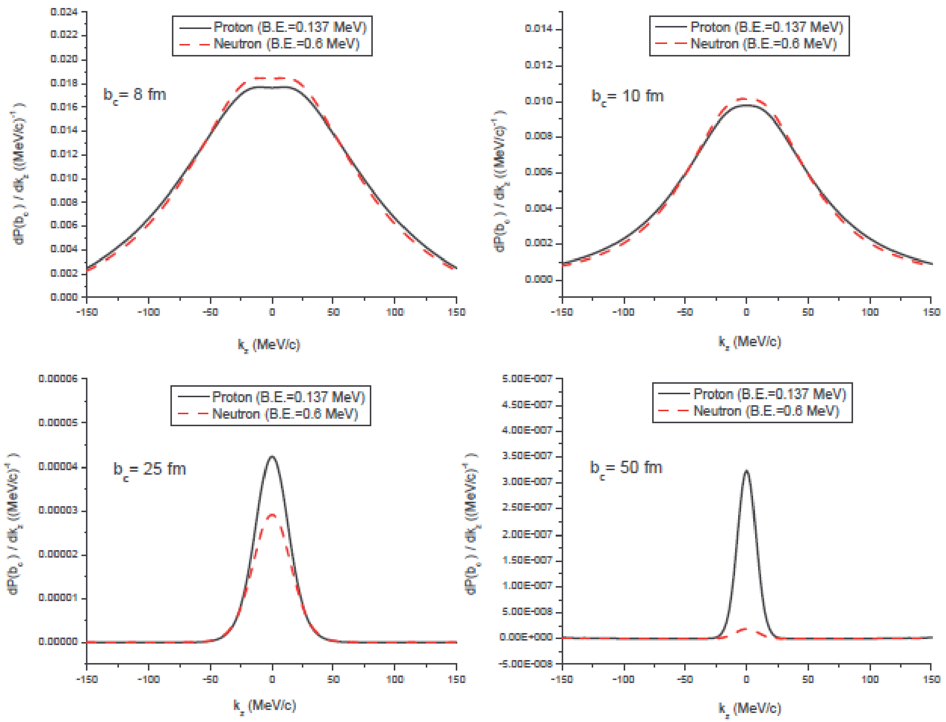


Fig. 4. Angular distributions of exclusive breakup for (a) ^{17}F + ^{58}Ni and (b) ^{17}F + ^{208}Pb. The dynamical calculation including the proton-target Coulomb field is shown by the dashed curves and the combined Coulomb and nuclear fields is shown by the solid curves. The dotted curve in (b) is for the perturbation calculation using an effective binding energy of 1.2 MeV (see text).

R. Kumar & AB, in preparation

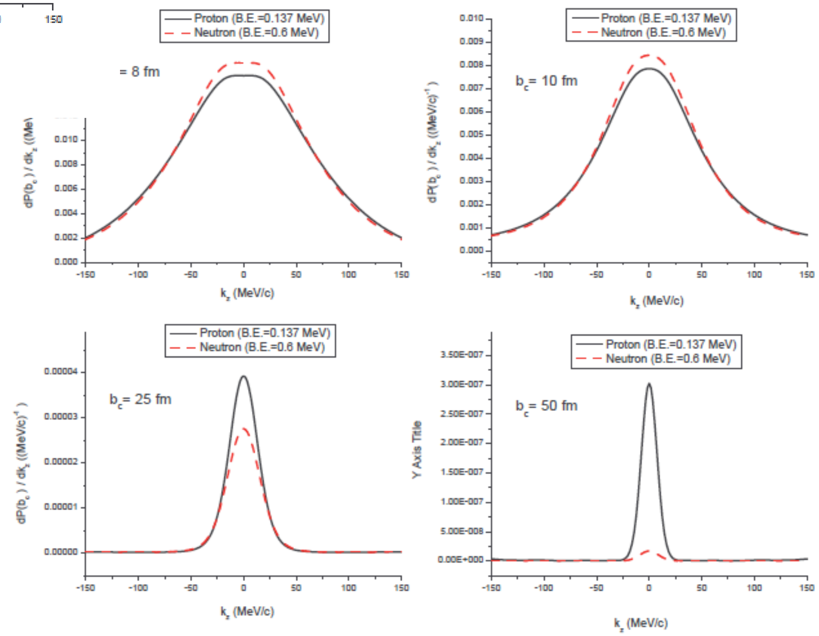


8B+208Pb at 72 MeV/n in Strip. reaction



Nuclear breakup: dominant if target is light

8B+208Pb at 72 MeV/n in Diff. reaction



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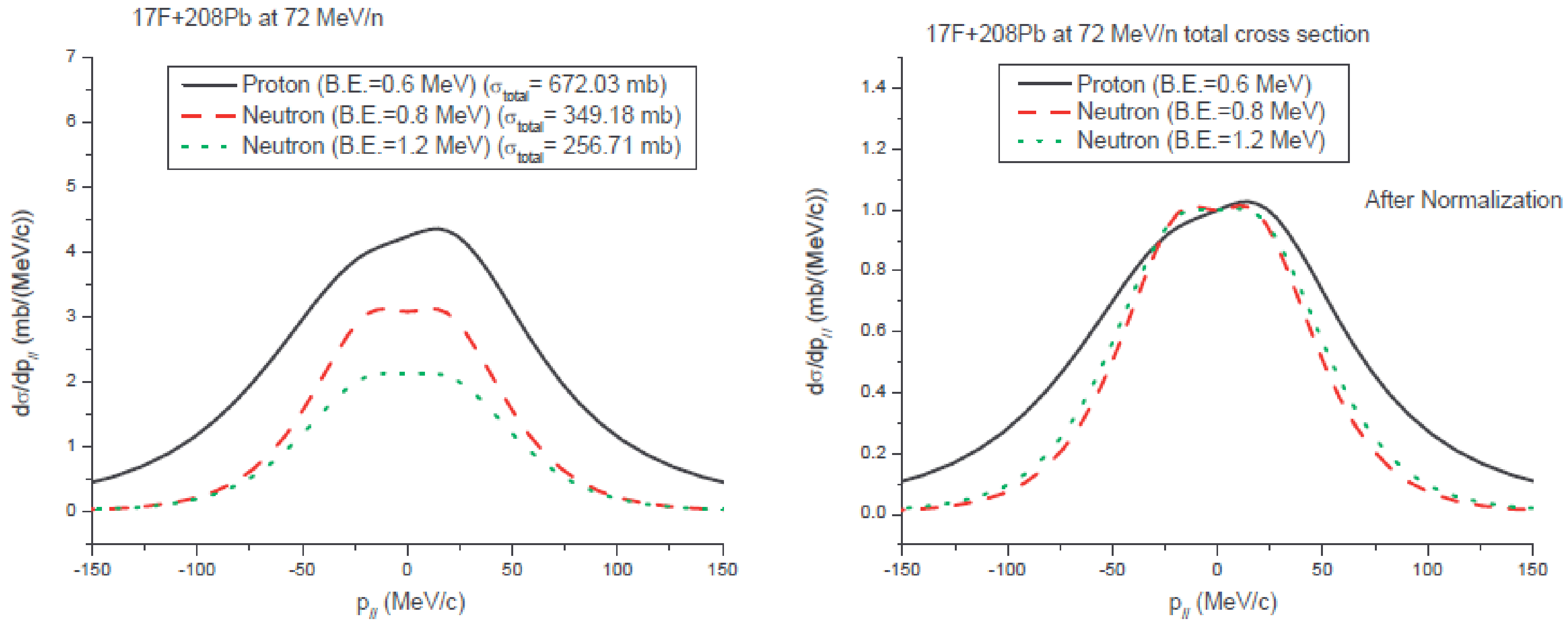
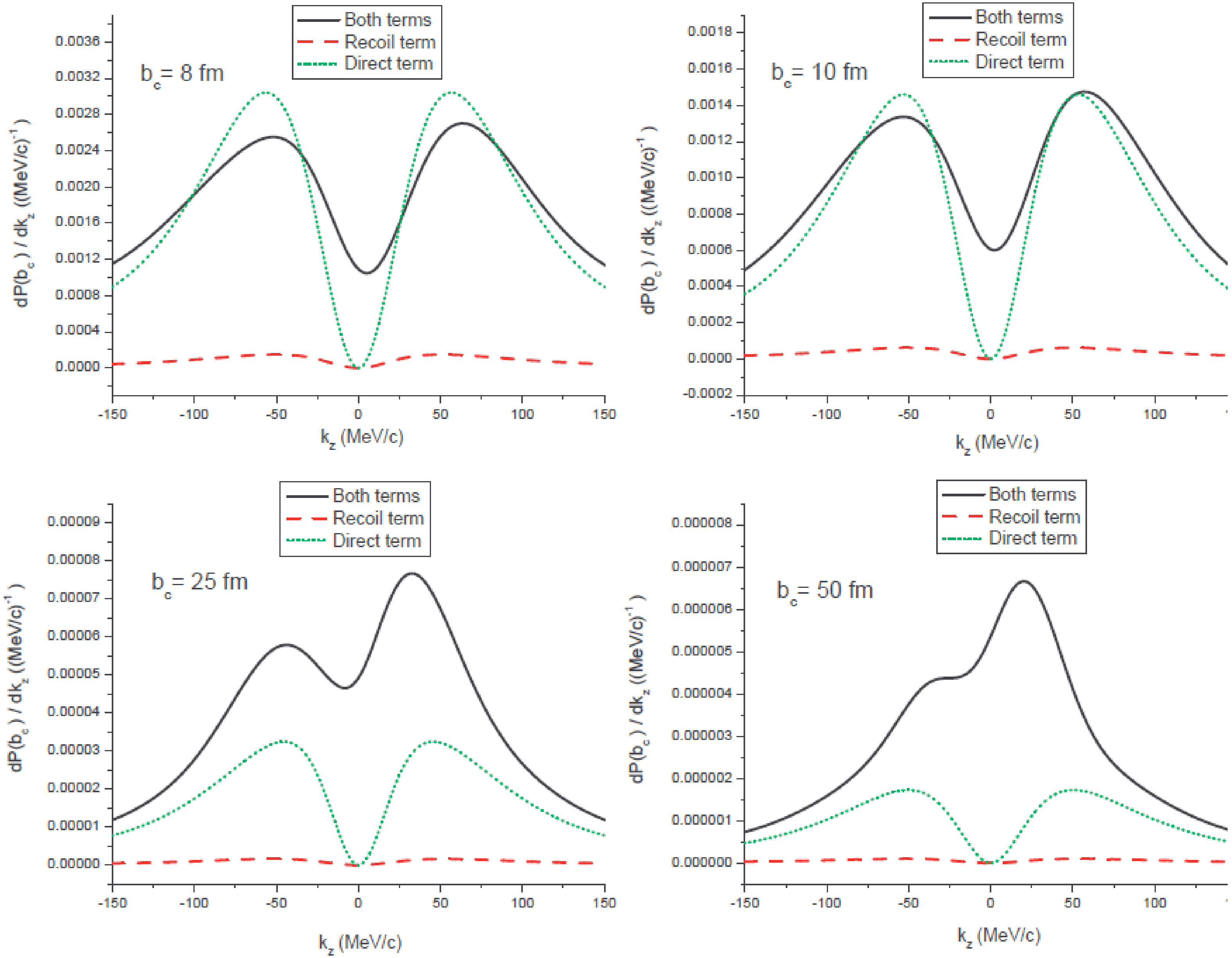
The case of a $d_{5/2}$ wf



Polarization effects ONLY in proton

17F+208Pb at 72 MeV/n contribution of Direct and Recoil terms (l=2,m=1)



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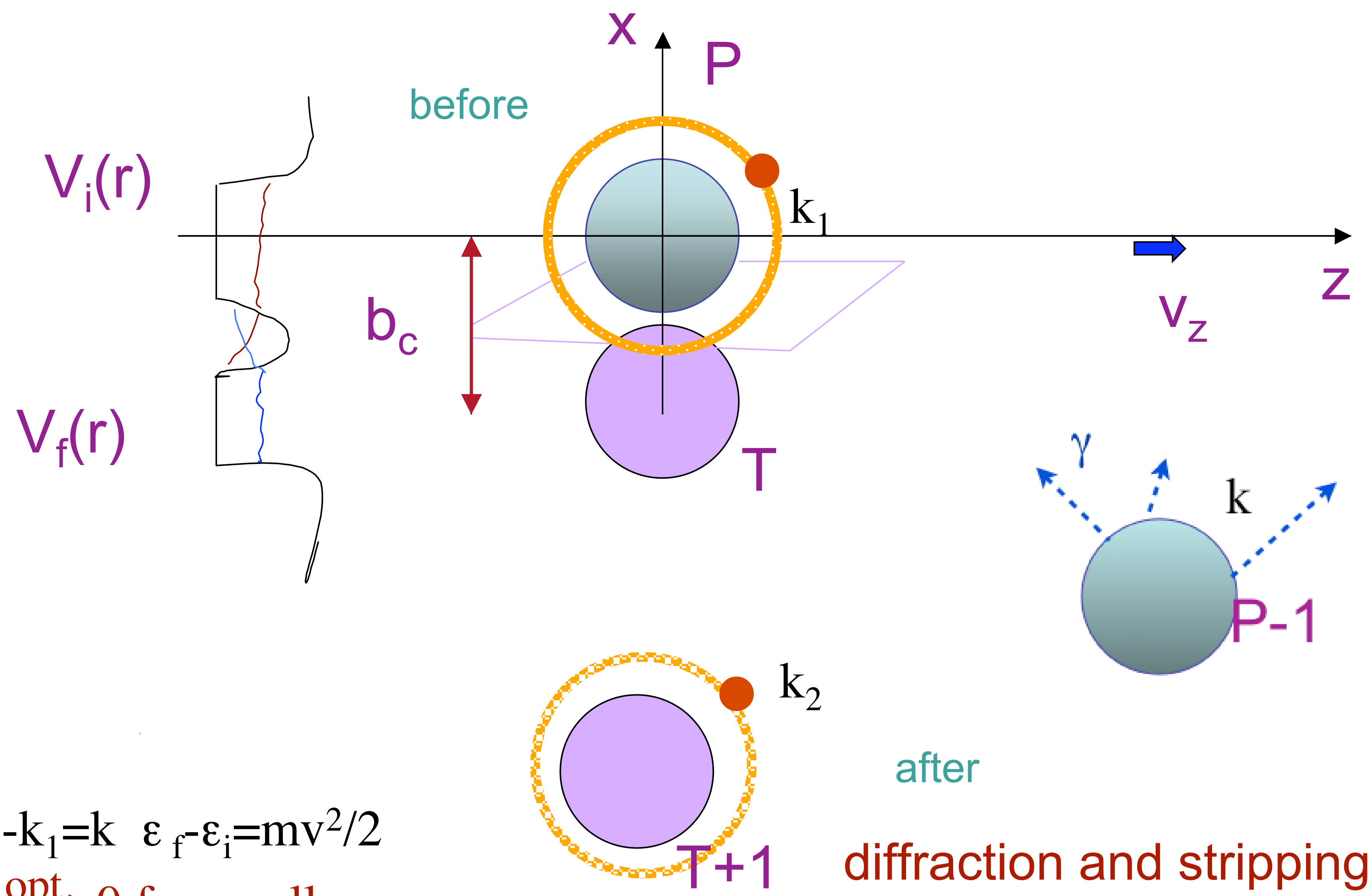
Transfer to the continuum
(breakup with final state interaction with the target)



diffraction and stripping

$k_2 - k_1 = k \quad \varepsilon_f - \varepsilon_i = mv^2/2$

$\boldsymbol{\varepsilon_f}^{opt} > 0$ for small $\boldsymbol{\varepsilon_i}$

Angela Bonaccorso

PHYSICAL REVIEW C VOLUME 49, NUMBER 1 JANUARY 1994

Inclusive spectra of stripping reactions induced by heavy ions

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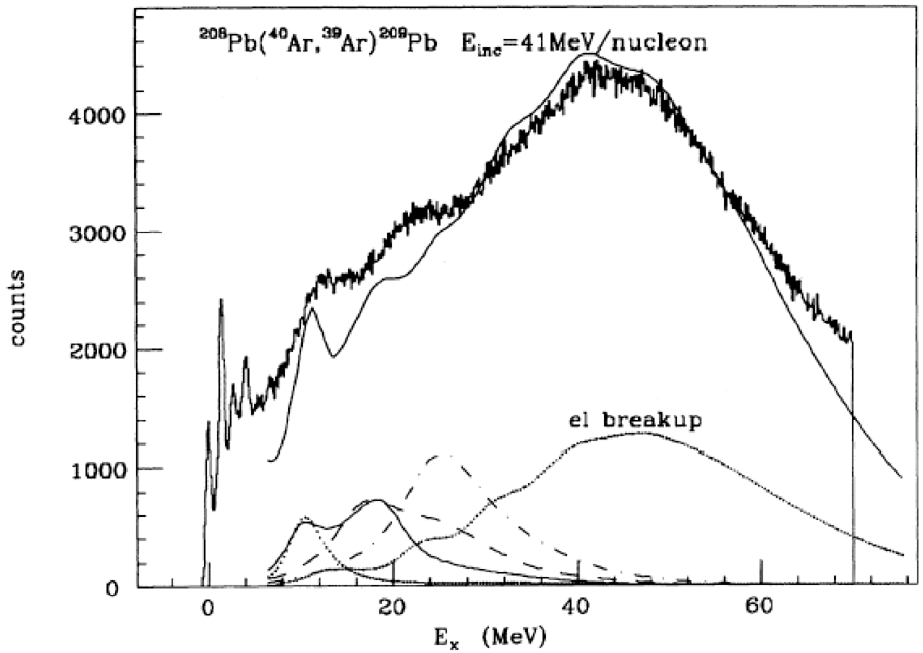
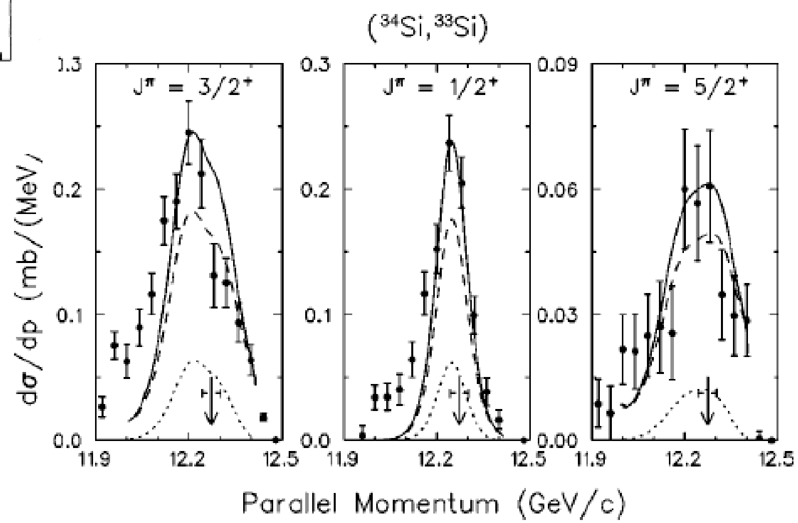
I. Lhenry and T. Suomijärvi
Institut de Physique Nuclèaire, Centre National de la Recherche Scientifique–Institut National de Physique Nucleàire et de {06 Orsay, France



J.Enders et al. PHYSICAL REVIEW C **65** 034318



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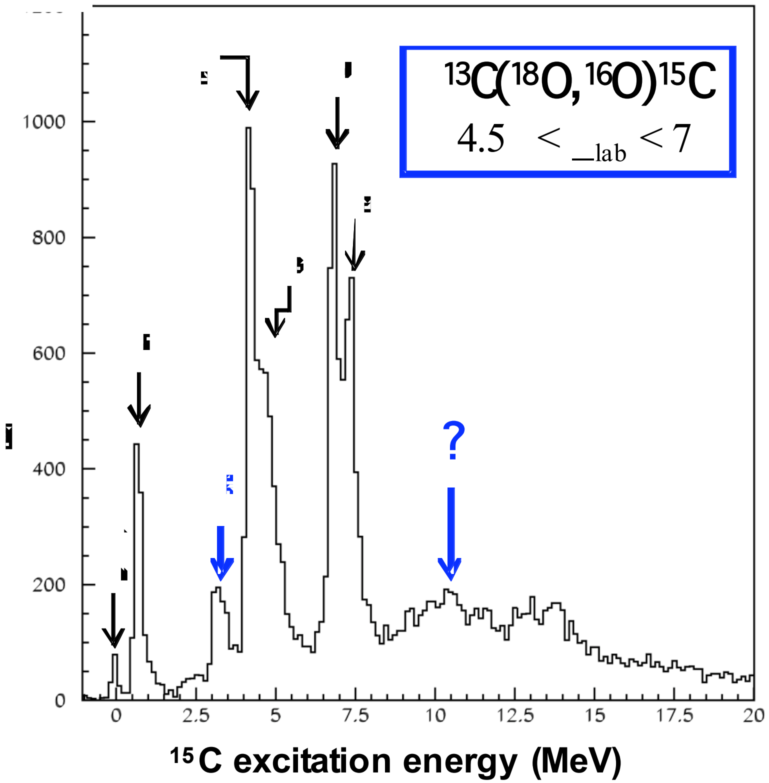
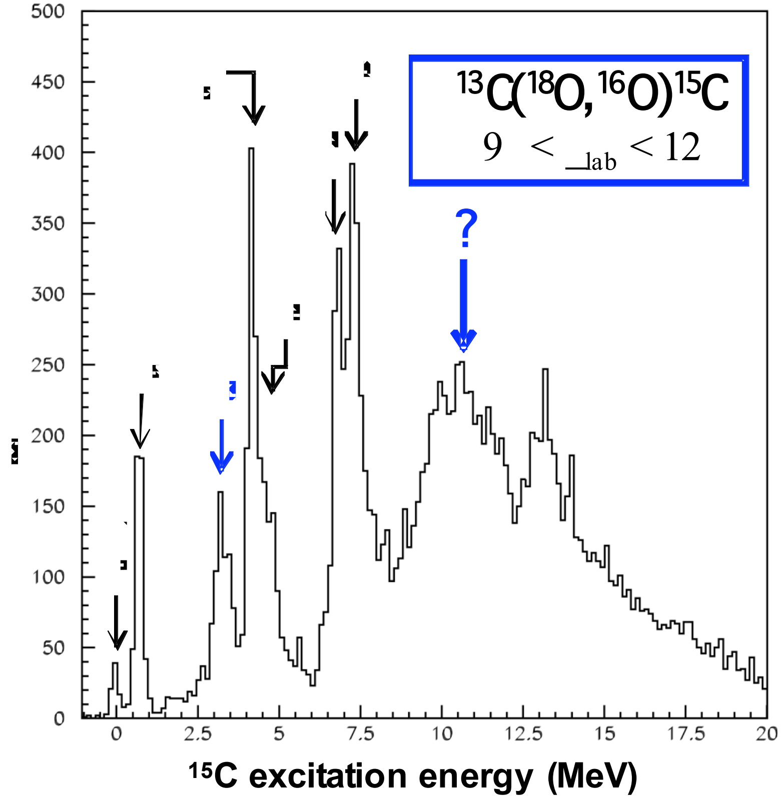
Preliminary spectra of ^{15}C





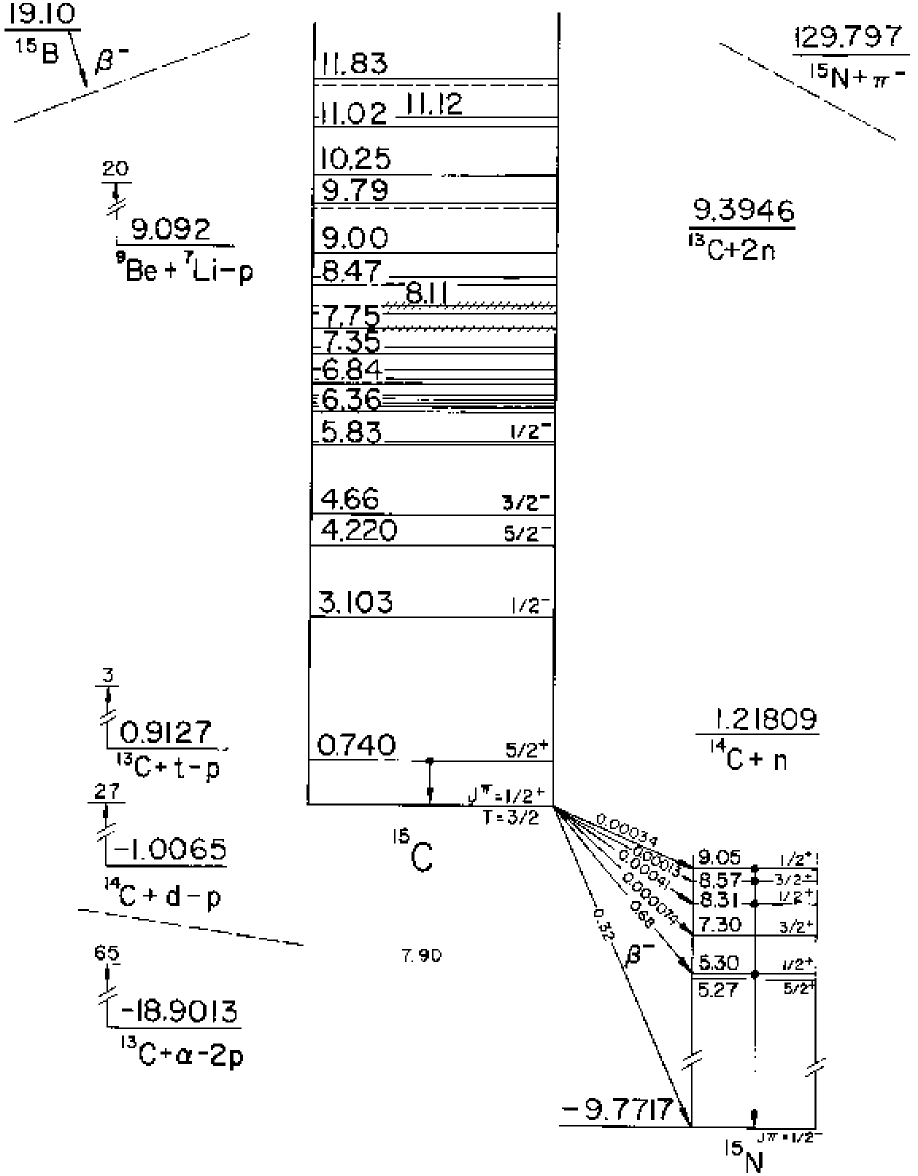
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{gs}$ (1/2$^+$)		**L = 1**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{0.74}$ (5/2$^+$)		**L = 3**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{3.103}$ (1/2$^-$)		**L = 0**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{4.22}$ (5/2$^-$)		**L = 2**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{4.66}$ (3/2$^-$)		**L = 2**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{6.84}$ (7/2$^-$, 9/2$^-$)		**L = 4**
$^{13}C_{g.s.}$ (1/2$^-$) _	$^{15}C_{7.35}$ (7/2$^-$, 9/2$^-$)		**L = 4**

S.Truong and H.T.Fortune, PRC 28,977(1983)

Enhancement of the known L=0 transition (state at 3.103 MeV) and of the 11 MeV bump

- Angular distributions in progress
- Break-Up calculations in progress

Good candidate for GPV?


19.10
15B
β-
129.797
15N+π-
20
9.092
9Be+7Li-p
9.3946
13C+2n
11.83
11.02
11.12
10.25
9.79
9.00
8.47
8.11
7.75
7.35
6.84
6.36
5.83 1/2-
4.66 3/2-
4.220 5/2-
3.103 1/2-
0.740 5/2+
Jπ=1/2+
T=3/2
15C
3
0.9127
13C+t-p
1.21809
14C+n
27
-1.0065
14C+d-p
7.90
65
-18.9013
13C+α-2p
0.00034
0.00013
0.00041
0.000074
0.68
0.32
β-
9.05 1/2+
8.57 3/2+
8.31 1/2+
7.30 3/2+
5.30 1/2+
5.27 5/2+
-9.7717
Jπ=1/2-
15N

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$^{18}O+^{13}C \longrightarrow ^{16}O+^{15}C$ 84MeV, LNS MAGNEX data

F. Cappuzzello, M. Cavallaro, A. Cunsolo et al.