VIIth Topical Workshop on
Modern Aspects in Nuclear Structure

The Many Facets of Nuclear Structure

BORMIO 3-8 February 2025

SYMPOSIUM on Resonances and related topics

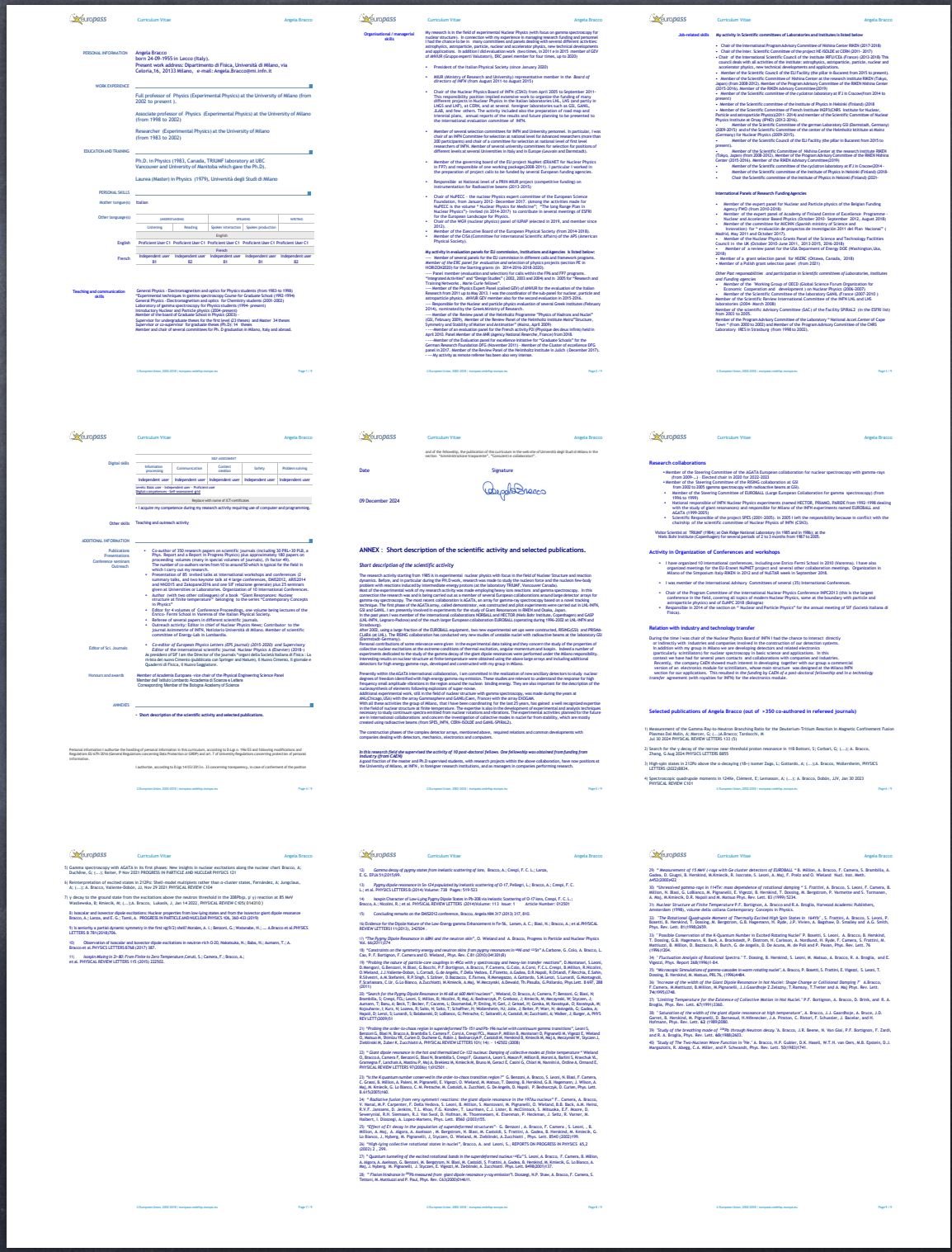
for Angela Bracco University retirement

Edoardo G. Lanza
INFN - Sezione di Catania

Eur. Phys. J. A (2015) **51**: 99

Angela Bracco is a full Professor at the University of Milano and she is associated to INFN. Her research experience is in nuclear structure and she obtained relevant results on the giant dipole resonance at zero and finite temperature. She was involved in the realization of complex detection system for gamma-ray built in European collaboration (EUROBALL, RISING and AGATA). In 2005–2011 she chaired the Nuclear Physics board of INFN and presently she is the chair of NuPECC (the European expert committee for Nuclear science).

Angela CV
(probably not the last one)



- She got her first degree " Laurea in Fisica" at Milano University.
- Ph.D. in Physics at TRIUMF laboratory at UBC Vancouver and University of Manitoba, Canada.
- Full professor of Physics at the Milano University.

At present:

- President of the Italian Physics Society (SIF). (Bologna)
- President of the Centro Ricerche Enrico Fermi (CREF). (Roma)

She has been :

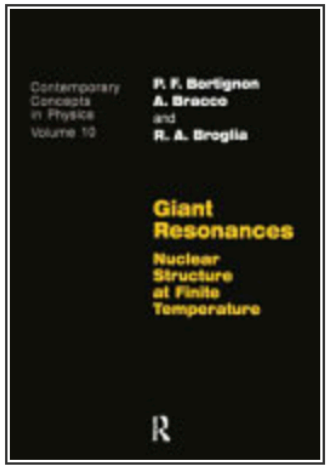
- Chair of the Nuclear Physics Board of INFN (CSN3).
- MIUR (Ministry of Research and University) representative member in the Board of Directors of INFN.
- Chair of NuPECC.
- Chair and member of many scientific committee.
- Member of several international evaluation panels.
- Member of several Scientific Committees of Laboratories and Research Institutions.

Involved in the realisation of detection system for gamma-ray (EUROBALL, RISING and AGATA).

- Co-Editor of European Physics Letters (EPS journal).
- Supervisory Editor of Nuclear Physics A.

- Author of more than 350 papers.
- 85 Invited talks.
- Referee of many papers in several scientific journals.

Giant Resonances: Nuclear Structure at Finite Temperature



P. F. Bortignon, Angela Bracco, R. A. Broglia

Harwood Academic Publishers, 1998 - 275 páginas

The series of volumes, Contemporary Concepts in Physics, is addressed to the professional physicist and to the serious graduate student of physics. The subject of many-body systems constitutes a central chapter in the study of quantum mechanics, with applications ranging from elementary particle and condensed matter physics to the behaviour of compact stellar objects. Quantal size effects is one of the most fascinating facets of many-body physics; this is testified to by the developments taking place in the study of metallic clusters, fullerenes, nanophase materials, and atomic nuclei. This book is divided into two main parts: the study of giant resonances based on the atomic nucleus ground state (zero temperature), and the study of the y-decay of giant resonances from compound (finite temperature) nuclei.

« Menos

Her first paper
(according to INSPIRE)

VOLUME 50, NUMBER 22 PHYSICAL REVIEW LETTERS 30 MAY 1983

Study of Two-Nucleon Wave Functions in ^{3}He

A. Bracco,[a] H. P. Gubler,[a] D. K. Hasell,[a] and W. T. H. van Oers[a]
University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

and

M. B. Epstein and D. J. Margaziotis
California State University, Los Angeles, California 90032

and

R. Abegg and C. A. Miller
TRIUMF, Vancouver, British Columbia V6T 2A3, Canada

and

H. Postma
Technische Hogeschool Delft, 2628 CJ Delft, The Netherlands

and

A. W. Stetz
Oregon State University, Corvallis, Oregon 97331

and

P. Schwandt
Indiana University, Bloomington, Indiana 47401
(Received 2 December 1982)

VOLUME 59, NUMBER 13 PHYSICAL REVIEW LETTERS 28 SEPTEMBER 1987

Limits of Collective Motion in Hot Nuclear Matter

J. J. Gaardhøje, A. M. Bruce, J. D. Garrett, and B. Herskind
The Niels Bohr Institute, University of Copenhagen, Copenhagen 2100 Ø, Denmark

D. Barnéoud
Institut des Sciences Nucléaires de Grenoble, Grenoble 38041 Cedex, France

M. Maurel, H. Nifenecker, J. A. Pinston, P. Perrin, C. Ristori, and F. Schussler
Centre d'Etudes Nucléaires de Grenoble, Grenoble 38041 Cedex, France

and

A. Bracco and M. Pignanelli
Dipartimento di Fisica dell'Università and Istituto Nazionale de Fisica Nucleare, Sezione di Milano, Milano, Italy
(Received 29 June 1987)

Nuclear Physics A482 (1988) 421c–436c
North-Holland, Amsterdam

GIANT RESONANCE EXCITATION IN HEAVY ION COLLISIONS.
PROCEEDINGS, 1ST TOPICAL MEETING, LEGNARO, ITALY, SEPTEMBER 21-25, 1987

P.F. Bortignon(ed.), J.J. Gaardhoje(ed.), M. Di Toro(ed.)
1988

The Direct Neutron Decay of Giant Resonances in ^{208}Pb

A. Bracco

Dipartimento di Fisica Universita' di Milano
e INFN sezione di Milano
Via Celoria 16, 20133 Milano, Italy

VOLUME 62, NUMBER 18 PHYSICAL REVIEW LETTERS 1 MAY 1989

Saturation of the Width of the Giant Dipole Resonance at High Temperature

A. Bracco,[1,2] J. J. Gaardhøje,[1] A. M. Bruce,[1],[a] J. D. Garrett,[1],[b] B. Herskind,[1] M. Pignanelli,[1,2] D. Barnéoud,[3] H. Nifenecker,[3,4] J. A. Pinston,[3] C. Ristori,[3,4] F. Schussler,[3,4] J. Bacelar,[5] and H. Hofmann[5]
[1]*The Niels Bohr Institute, University of Copenhagen, Copenhagen 2100 Ø, Denmark*
[2]*Dipartimento di Fisica, Universitá di Milano and Instituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milano, Italy*
[3]*Institut des Sciences Nucleaires, 53 Ave. des Martyrs, Grenoble CEDEX 38026, France*
[4]*Centre d'Etudes Nucléaires de Grenoble, Département de Recherche Fondamentale, Service de Physique, Grenoble, France*
[5]*Kernfysisch Versneller Instituut, 9747 AA Groningen, The Netherlands*
(Received 14 November 1988)

... to make the long story short ... after hundreds of papers ...

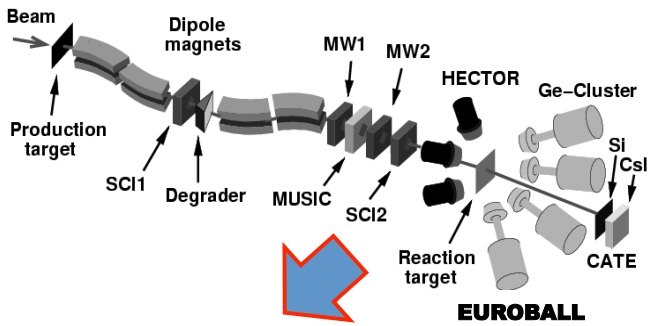
PRL 102, 092502 (2009) PHYSICAL REVIEW LETTERS week ending 6 MARCH 2009

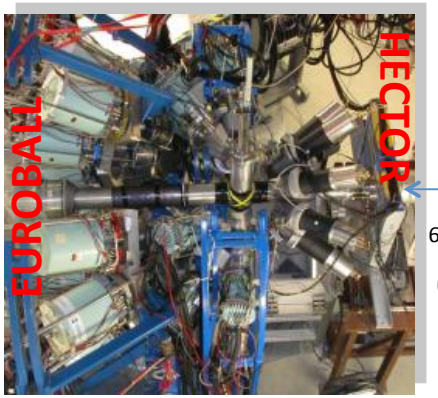
Search for the Pygmy Dipole Resonance in ^{68}Ni at 600 MeV/nucleon

O. Wieland,[1] A. Bracco,[1,2] F. Camera,[1,2] G. Benzoni,[1] N. Blasi,[1] S. Brambilla,[1] F. C. L. Crespi,[1,2] S. Leoni,[1,2] B. Million,[1] R. Nicolini,[1,2] A. Maj,[3] P. Bednarczyk,[3] J. Grebosz,[3] M. Kmiecik,[3] W. Meczynski,[3] J. Styczen,[3] T. Aumann,[4] A. Banu,[4] T. Beck,[4] F. Becker,[4] L. Caceres,[4,*] P. Doornenbal,[4,†] H. Emling,[4] J. Gerl,[4] H. Geissel,[4] M. Gorska,[4] O. Kavatsyuk,[4] M. Kavatsyuk,[4] I. Kojouharov,[4] N. Kurz,[4] R. Lozeva,[4] N. Saito,[4] T. Saito,[4] H. Schaffner,[4] H. J. Wollersheim,[3] J. Jolie,[5] P. Reiter,[5] N. Warr,[5] G. deAngelis,[6] A. Gadea,[6] D. Napoli,[6] S. Lenzi,[7,8] S. Lunardi,[7,8] D. Balabanski,[9,10] G. LoBianco,[9,10] C. Petrache,[9,‡] A. Saltarelli,[9,10] M. Castoldi,[11] A. Zucchiatti,[11] J. Walker,[12] and A. Bürger[13,§]

Pygmy dipole resonance in ^{68}Ni

RISING-SETUP=EUROBALL and HECTOR @ GSI





^{68}Ni-Beam
600AMeV

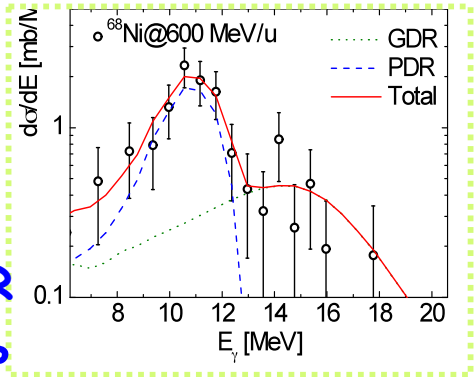
Relativistic Heavy-ion Coulomb Excitation: Virtual Photon Scattering

Pygmy in ^{68}Ni at 11 MeV

Width ≈ 2 MeV mainly due to Doppler Broadening

5 (p/m 1.5) % of the EWSR
B(E1) = 1.2 e²fm²

PDR 5%

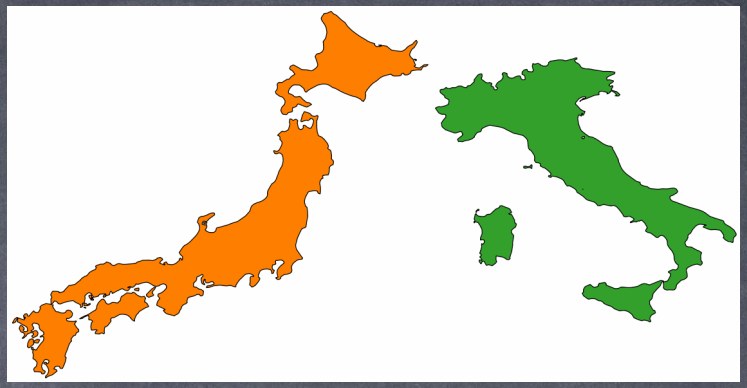


O. Wieland et al., PRL102(2009)092502

Ettore Majorana School,
Erice 1986

8th Japan - Italy Symposium

RIKEN 7 - 10 March 2016




WYDZIAŁ INŻYNIERII
MATERIAŁOWEJ I CERAMIKI
B-6
COMEX5
September 14-18, 2015 Kraków, Poland

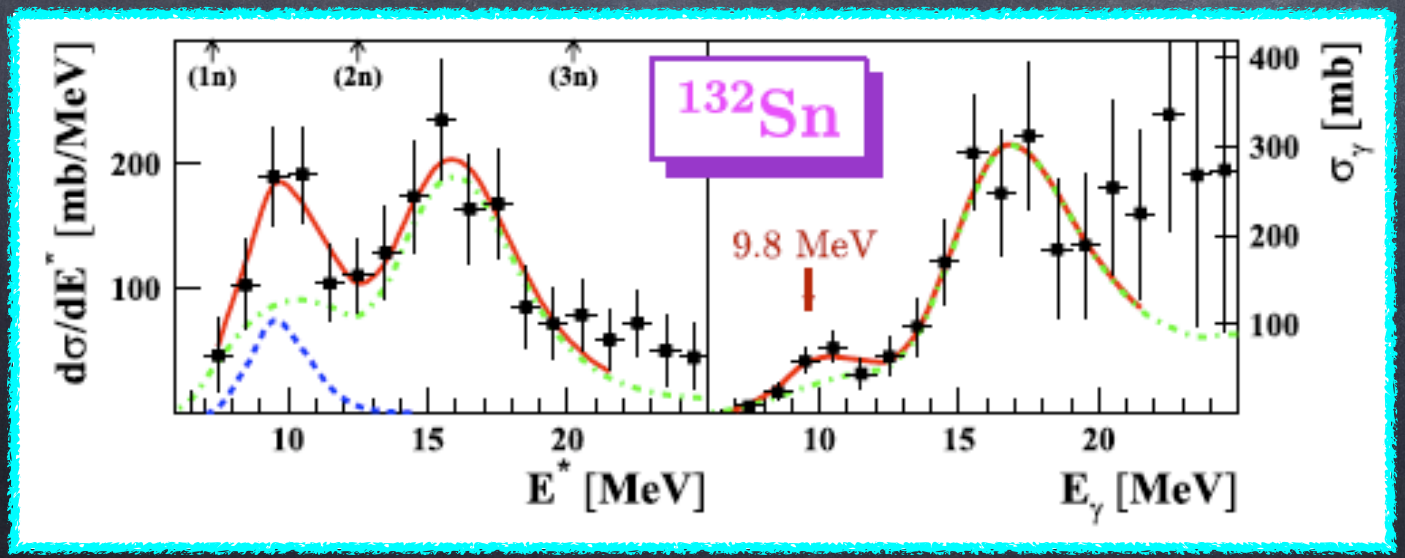
The Pygmy Dipole Resonances (PDR) are dipole states located at much lower energy than the GDR peak.

They were called "pygmy" because their strength are much smaller than GDR.
They exhaust only few per cent of the IVEWSR.

They are present in all the nuclei with neutron excess.
Therefore, they should be more evident in nuclei far from the stability line

^{132}Sn + ^{208}Pb @ 500 MeV/u

P.Adrich et al., PRL 95 (2005) 132501



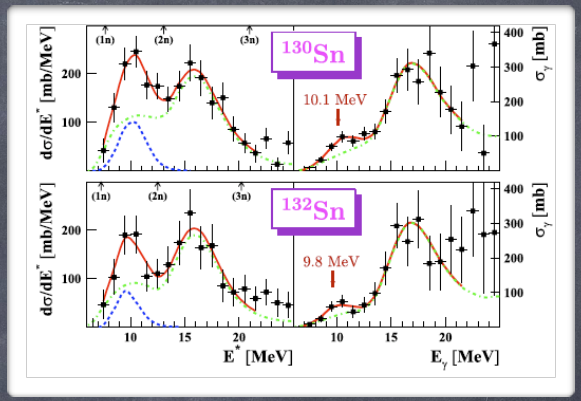
Pygmy Dipole Resonance Experimental data

ABOVE NEUTRON SEPARATION THRESHOLD

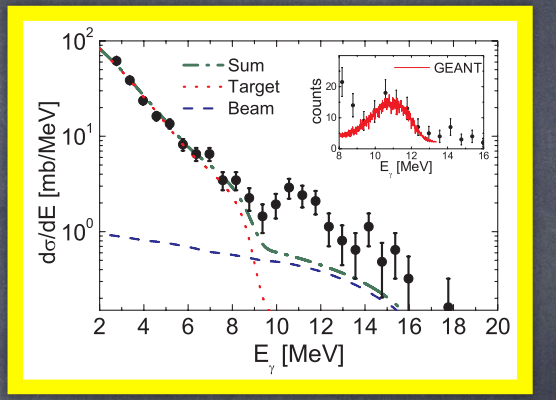
exotic nuclei

- using the FRS-LAND setup at GSI →
- using the RISING setup at GSI (for ^{68}Ni)

P.Adrich et al. PRL 95 (2005) 132501
O.Wieland et al. PRL 102 (2009) 092502



^{68}Ni

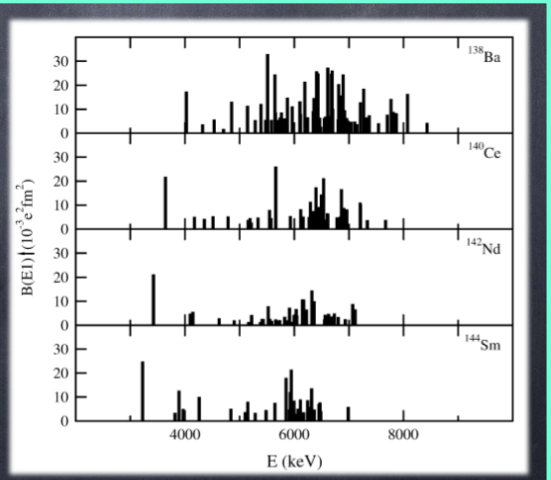


BELOW NEUTRON SEPARATION THRESHOLD

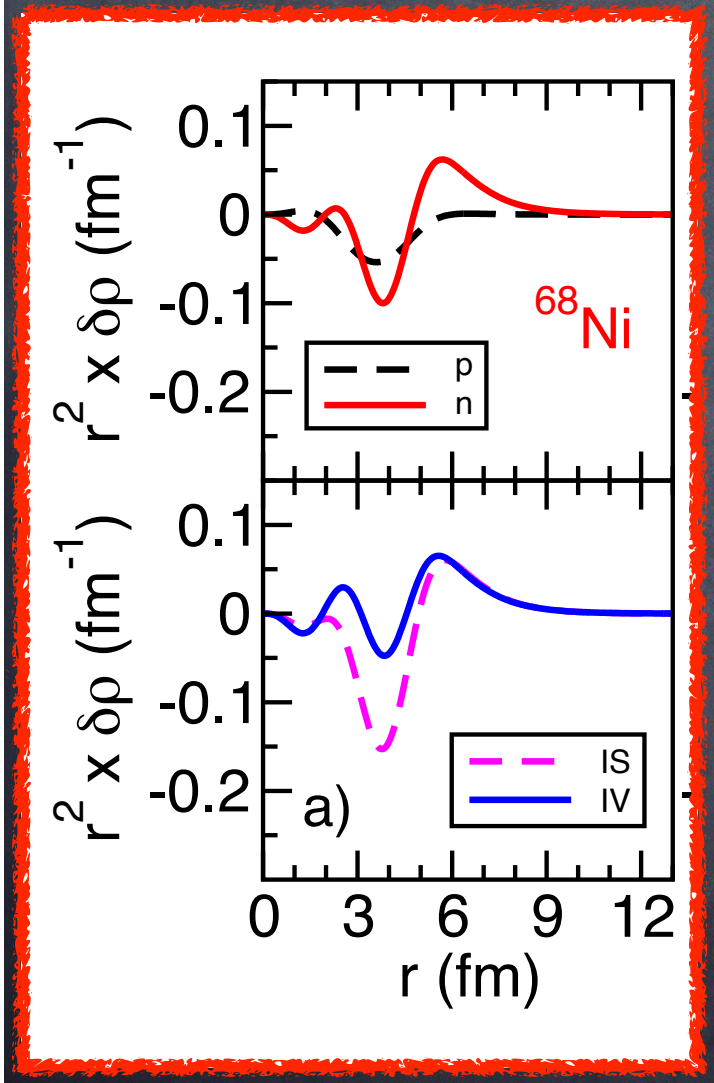
stable nuclei

- with (γ,γ') studies (Darmstadt University)
- with $(\alpha,\alpha'\gamma)$ at KVI.
- with $(^{17}O,^{17}O'\gamma)$ at LNL

D.Savran et al. PRL 100 (2008) 232501
J.Endres et al. PRC 80 (2009) 034302
F.C.L.Crespi et al. PRL113(2014)012501



It is well established that the low-lying dipole states (the Pygmy Dipole Resonance) have a strong isoscalar component.



Neutron and Proton transition densities are in phase inside the nucleus;
at the surface only the neutron part contribute.

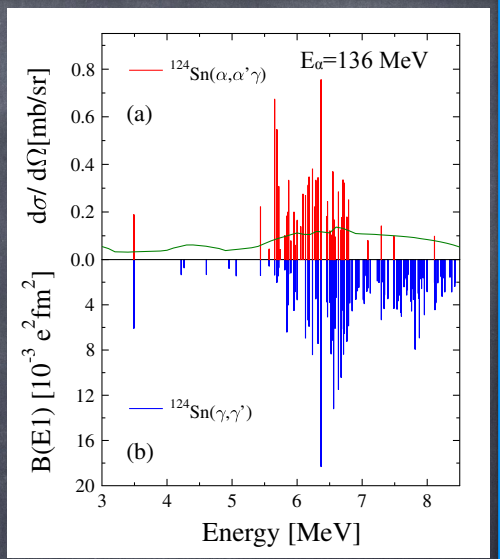
"Theoretical definition" of the PDR

It is possible to study these states also via an isoscalar probe

Splitting of the low-lying dipole strength

- with $(\alpha,\alpha'\gamma)$ at KVI.
- with $(^{17}O, ^{17}O'\gamma)$ at LNL

D. Savran et al., PRL 97 (2006)172502
J. Endres et al., PRC 80 (2009) 034302
J. Enders et al., PRL 105 (2010) 212503
F.C.L. Crespi et al. PRL 113 (2014) 012501



By using different reactions employing electromagnetic and hadronic probes of different types (like α-particle, ^{17}O, ^{12}C and p) one is expected to be sensitive to different regions on the nuclear volume and thus the comparison of the results provides indication on the nature of these states

In these cases also the inelastic cross section is measured and therefore it is of paramount importance to calculate it

In the experimental analysis, for these cases, a fundamental role is played by the radial form factors used

The description of inelastic cross section with isoscalar probes

- DWBA, first order theory
- Coupled Channel, high order effect important
- Semiclassical approximations

Example: the transition amplitude for the DWBA

$$T^{DWBA} = \int \chi^{(-)}(k_\beta, r) F(r) \chi^{(+)}(k_\alpha, r) dr$$

the radial form factor $F(r)$ contains all the structure properties, they can be derived in macroscopic or microscopic approaches

$$F^C(r) \approx \frac{\sqrt{B(EL)}}{r^{L+1}}$$

$$F^N(r) \approx \beta_N \frac{dU^N(r)}{dr}$$

For the dipole radial form factors calculation one needs the radial transition densities

- Goldhaber-Teller for the IVGDR

$$\delta\rho^{GT}(r) = \beta_1\left[\frac{2N}{A}\frac{d}{dr}\rho_p(r) - \frac{2Z}{A}\frac{d}{dr}\rho_n(r)\right]$$

- Harakeh-Dieperink for the ISGDR

$$\delta\rho^{HD}(r) = -\frac{\beta_1}{R\sqrt{3}}\left[3r^2\frac{d}{dr} + 10r - \frac{5}{3} < r^2 > \frac{d}{dr} + \epsilon(r\frac{d^2}{dr^2} + 4\frac{d}{dr})\right]\rho_0(r)$$

- Microscopic transition densities (RPA or more sofphisticated approaches)

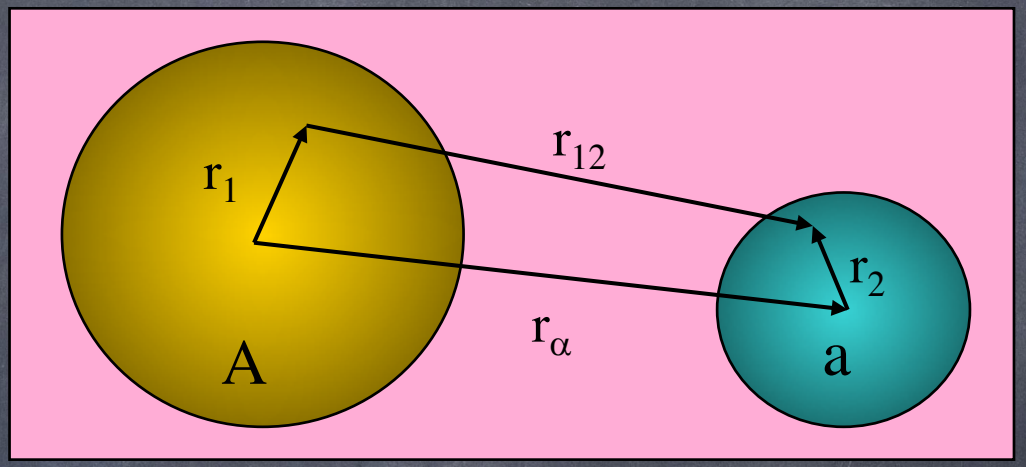
The nucleon nucleon interaction depends on the isospin

$$\nu_{12} = \nu_0(r_{12}) + \nu_1(r_{12})\tau_1 \cdot \tau_2$$

where τ_i are the isospin of the nucleons.

In the case $\rho_n = N/Z\,\rho$; $\rho_p = N/A\,\rho$, F_1 is zero when one of the two nuclei has $N=Z$.

Double Folding procedure

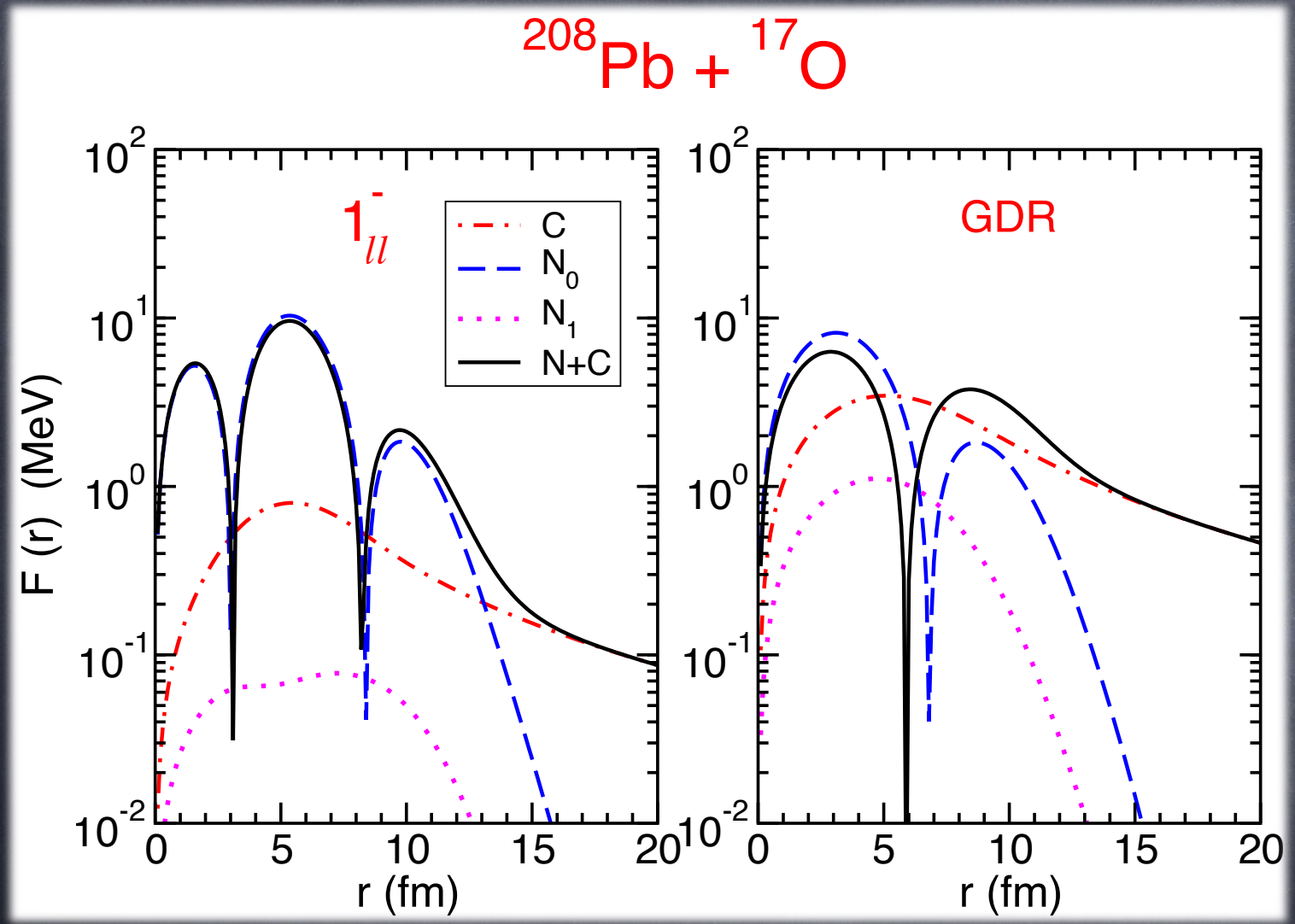


The nuclear form factors are

$$F_0(r_\alpha) = \int\int [\delta\rho_{A_n}(\vec{r}_1) + \delta\rho_{A_p}(\vec{r}_1)]\,\nu_0(r_{12})\,[\rho_{a_n}(\vec{r}_2) + \rho_{a_p}(\vec{r}_2)]\,r_1^2 dr_1 r_2^2 dr_2$$

$$F_1(r_\alpha) = \int\int [\delta\rho_{A_n}(\vec{r}_1) - \delta\rho_{A_p}(\vec{r}_1)]\,\nu_1(r_{12})\,[\rho_{a_n}(\vec{r}_2) - \rho_{a_p}(\vec{r}_2)]\,r_1^2 dr_1 r_2^2 dr_2$$

Folding done with the effective nucleon-nucleon M3Y interaction and with the RPA transition densities



The Coulomb contribution is very different for the two states, while the nuclear one is of the same order of magnitude.

Since the PDR are non collective, one cannot employ standard codes which make use of macroscopic form factors.

The nuclear and Coulomb parts interfere destructively at small radii and constructively at large radii. This is mainly due to isoscalar part and to the fact that the isoscalar dipole transition density displays nodes

In the semiclassical model the two nuclei move according to a classical trajectory while quantum mechanics is used to describe the internal degrees of freedom

$$H = H_A + H_B$$ where $$H_A = H_A^0 + W_A(t)$$

$$W_A(t) = \sum_{ij} < i|U_B(\vec{R}(t))|\, j > a_i^+ \, a_j + h.c.$$

t-dependence through R(t)

The time dependent state is $$|\Psi, t> = \sum_\alpha A_\alpha(t) e^{-iE_\alpha t} |\Phi_\alpha>$$

The Schrödinger equation can be cast into a set of coupled linear differential equations

$$\dot{A}_\alpha(t) = -i \sum_{\alpha'} e^{i(E_\alpha - E_{\alpha'})t} < \Phi_\alpha |W(t)| \Phi_{\alpha'} > A_{\alpha'}(t)$$

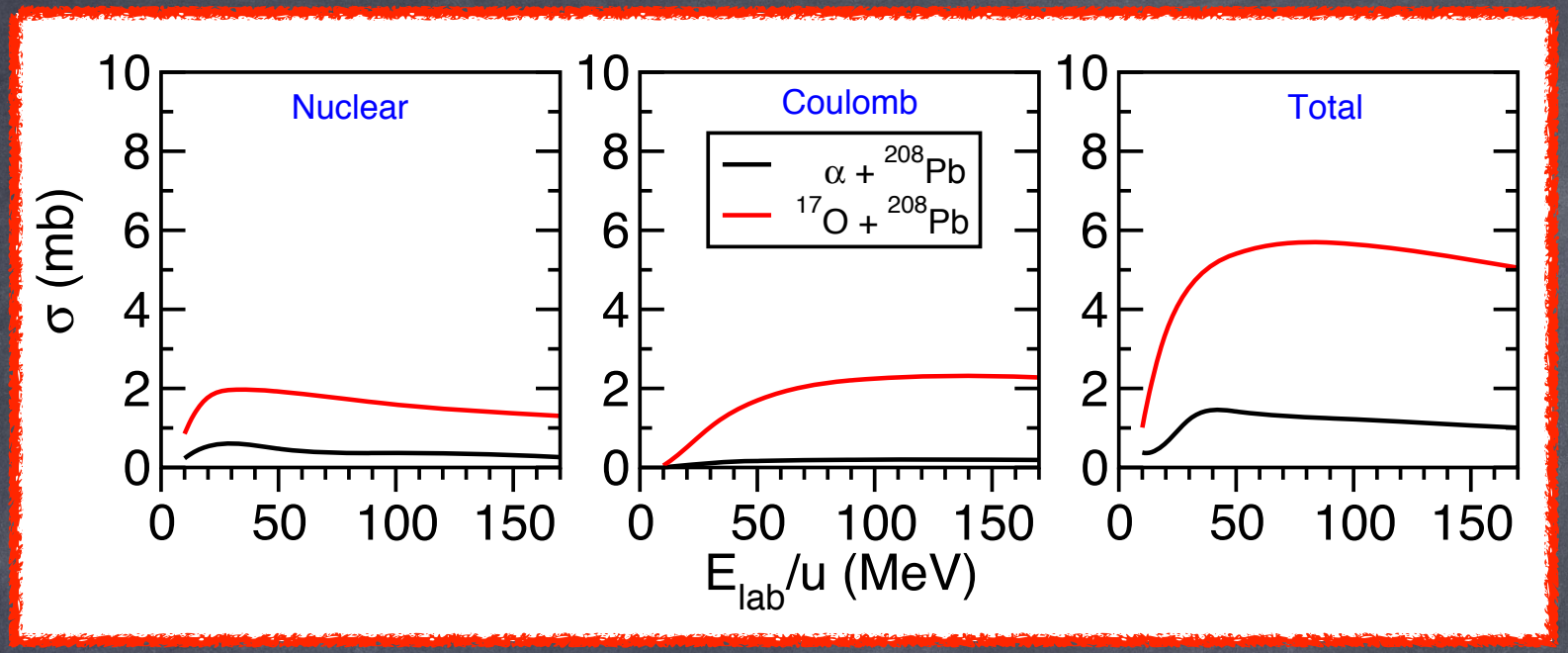
Probability to excite the state a as function of the impact parameter b

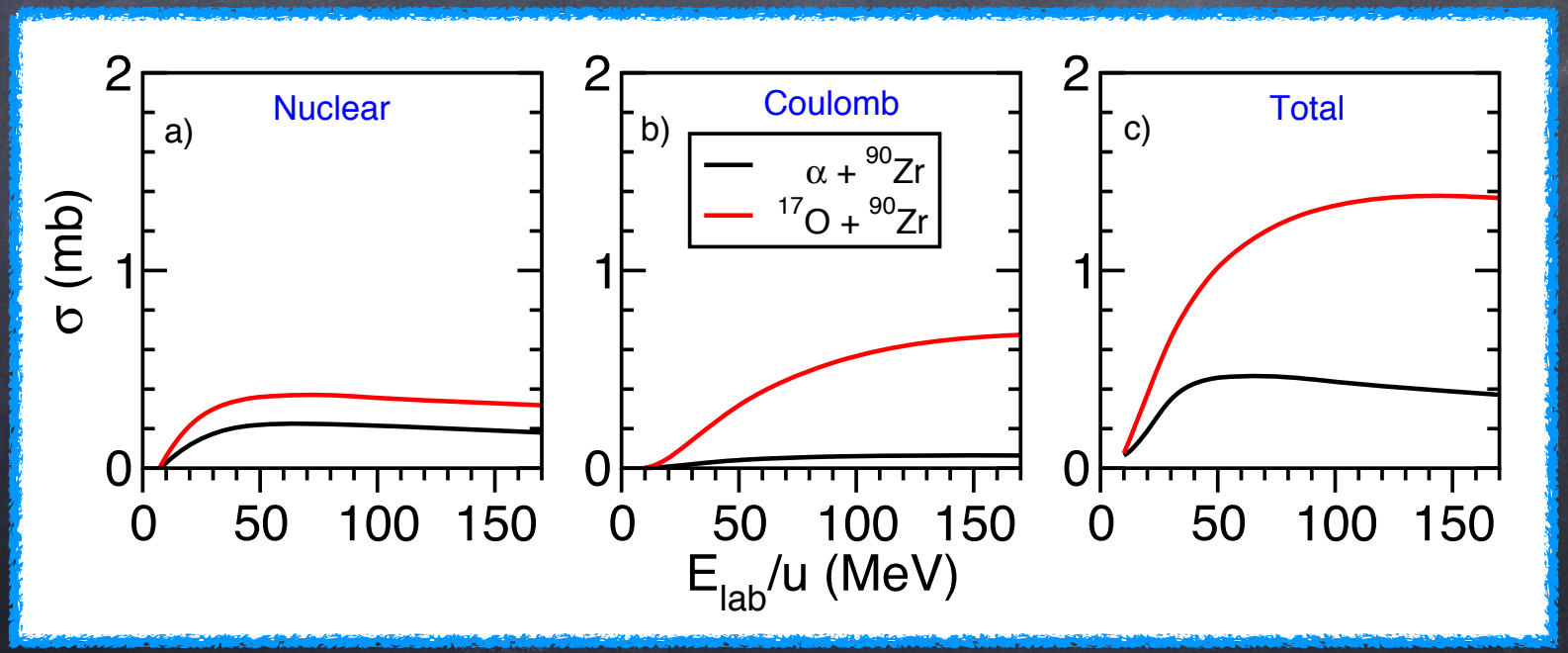
$$P_\alpha(b) = |A_\alpha(t=\infty)|^2$$

and its cross section is

$$\sigma_\alpha = 2\pi \int_0^{+\infty} P_\alpha(b) T(b) b \, db.$$

$T(b)$ the transmission coefficient


Nuclear
Coulomb
Total
α + 208Pb
17O + 208Pb
σ (mb)
Elab/u (MeV)
0
2
4
6
8
10
0
50
100
150


a)
Nuclear
b)
Coulomb
c)
Total
α + 90Zr
17O + 90Zr
σ (mb)
Elab/u (MeV)
0
1
2
0
50
100
150

Angela and her group started a campaign, at Laboratorio Nazionale di Legnaro, to investigate the structure of Pygmy resonances states. with an isoscalar probe.

A number of measurements were done using the (^{17}O,$^{17}O'$ γ) reaction at a bombarding energy of about 20 MeV/u.

The ^{208}Pb, ^{124}Sn and ^{90}Zr and ^{140}Ce nuclei were studied with this reaction.

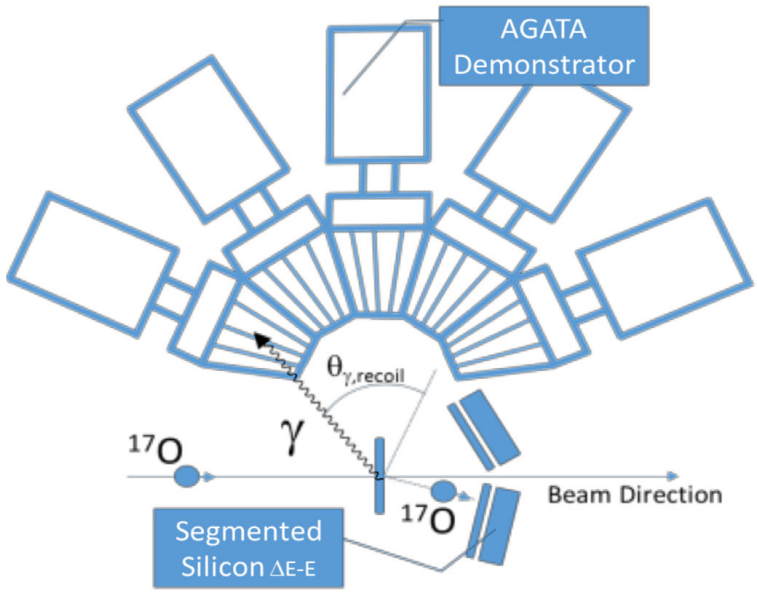
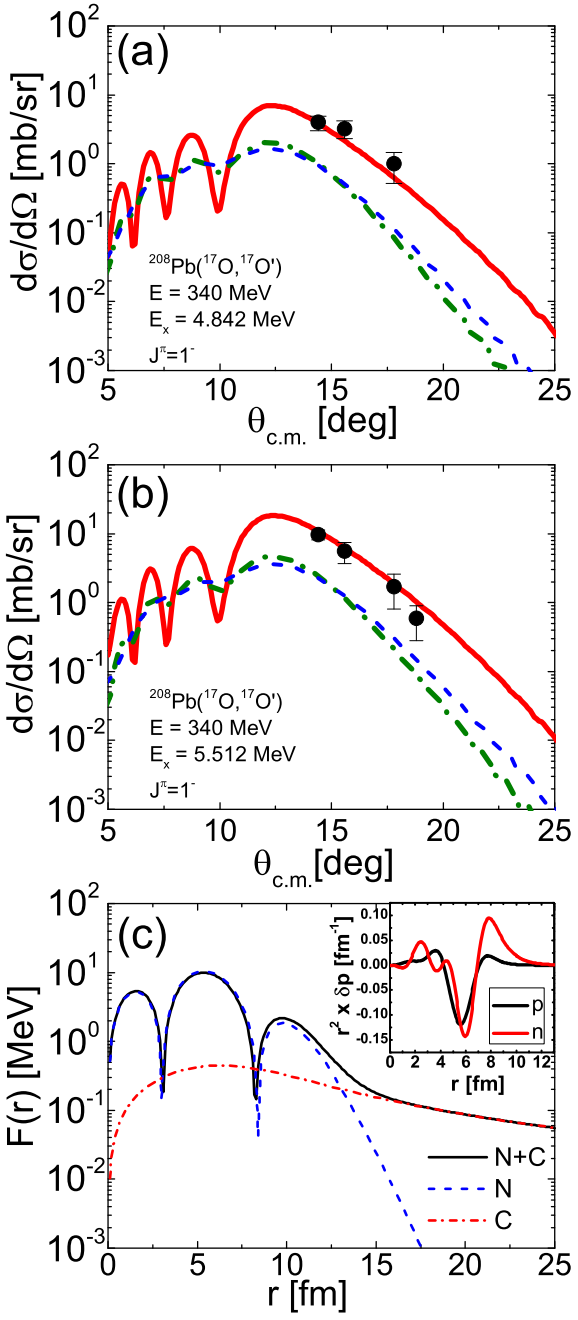


Fig. 10. Schematic representation of the experimental setup including segmented silicon detectors placed at forward angles and the AGATA HPGe detectors. The angle $\theta_{\gamma,\mathrm{recoil}}$ between the direction of the recoiling ^{208}Pb ions (dashed line) and of the gamma-ray (when a scattered ^{17}O is detected in the right silicon telescope) is displayed.

The analyses of the differential cross sections were performed within the framework of the Distorted Wave Born Approximation (DWBA).

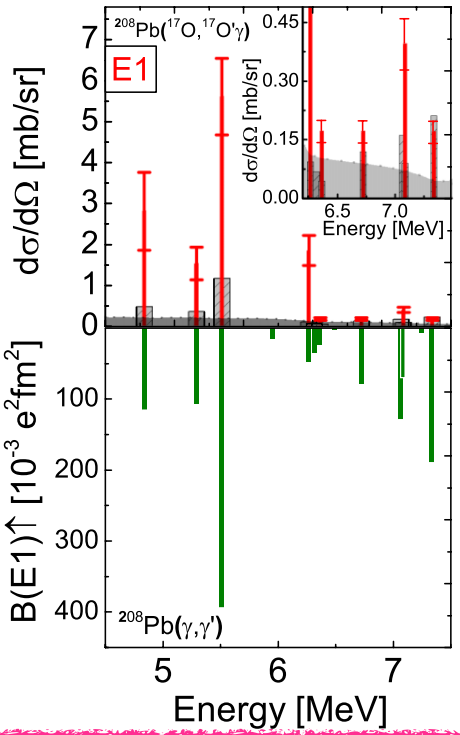
F.C.L. Crespi et al., PRL 113 (2014) 012501



^{208}Pb(^{17}O,^{17}O'γ)^{208}Pb at 340 MeV

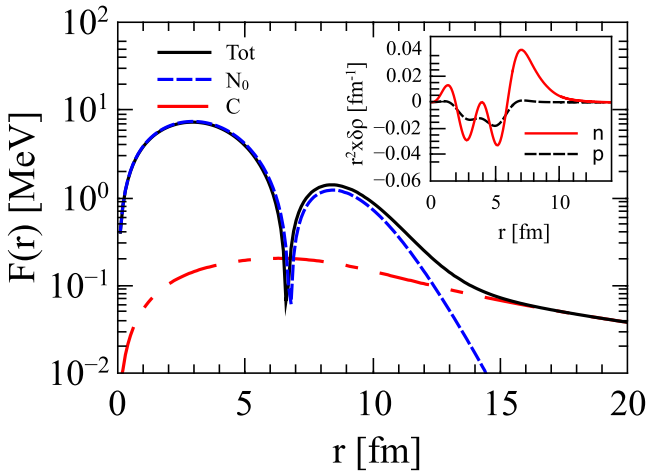
Using TRACE prototype and AGATA Demonstrator system

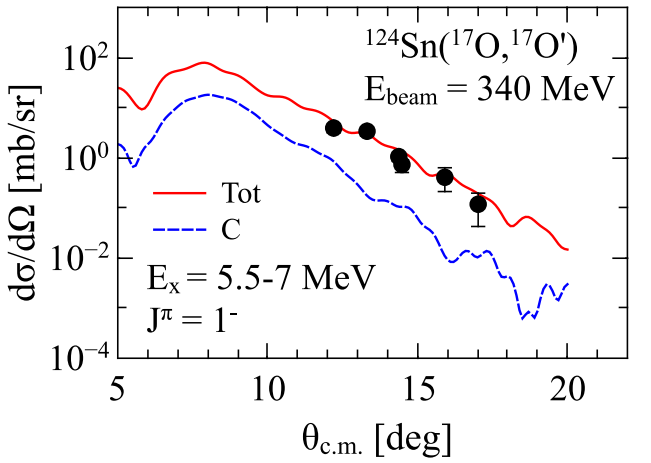
DWBA calculations (with FRESCO) using the microscopic form factors shown before

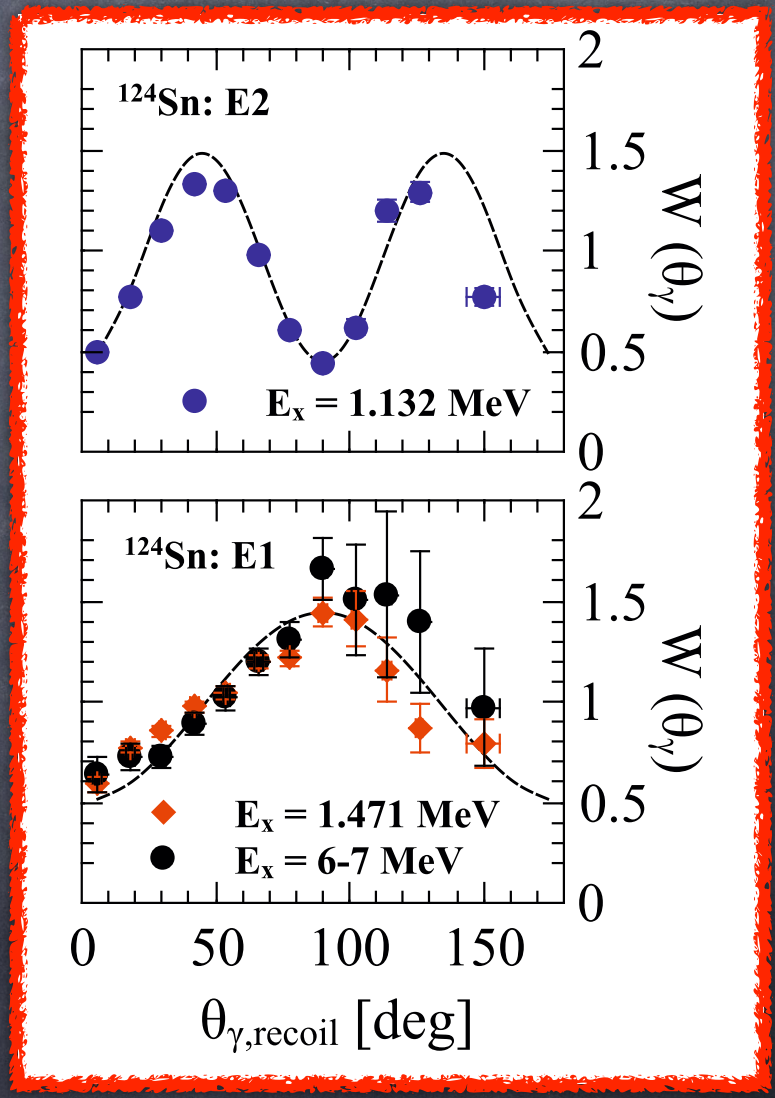


L. Pellegri et al.,
PLB 738 (2014) 519

^{124}Sn(^{17}O,^{17}Oγ)^{124}Sn
at 340 MeV

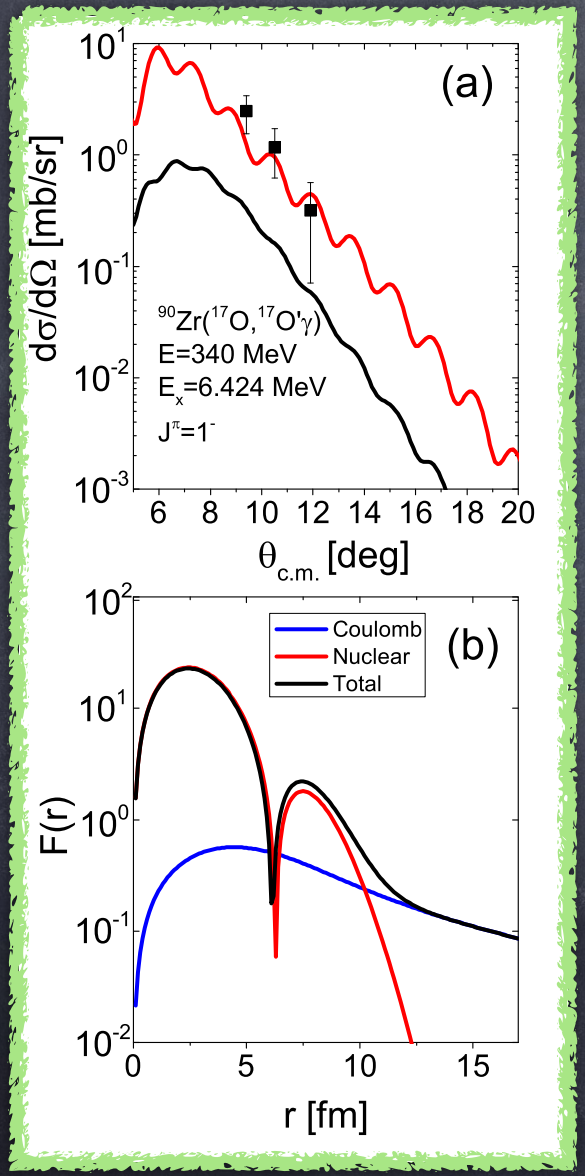


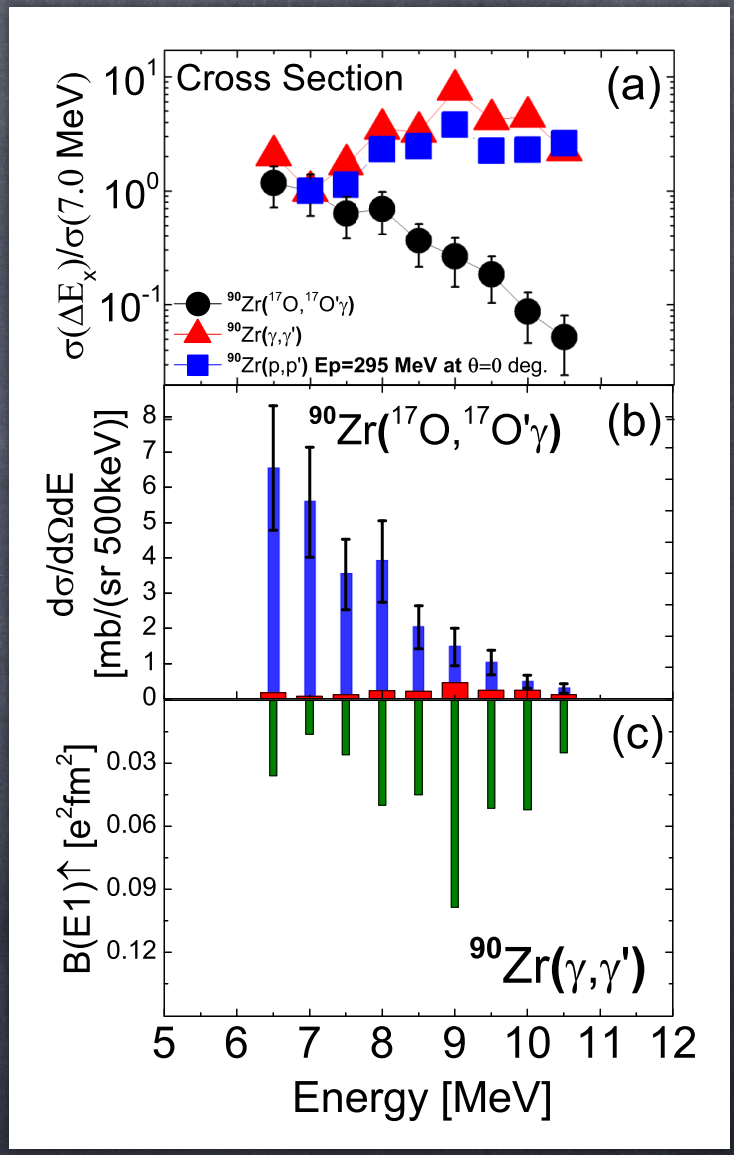




F.C.L. Crespi et al.,
PRC 91 (2015) 024323

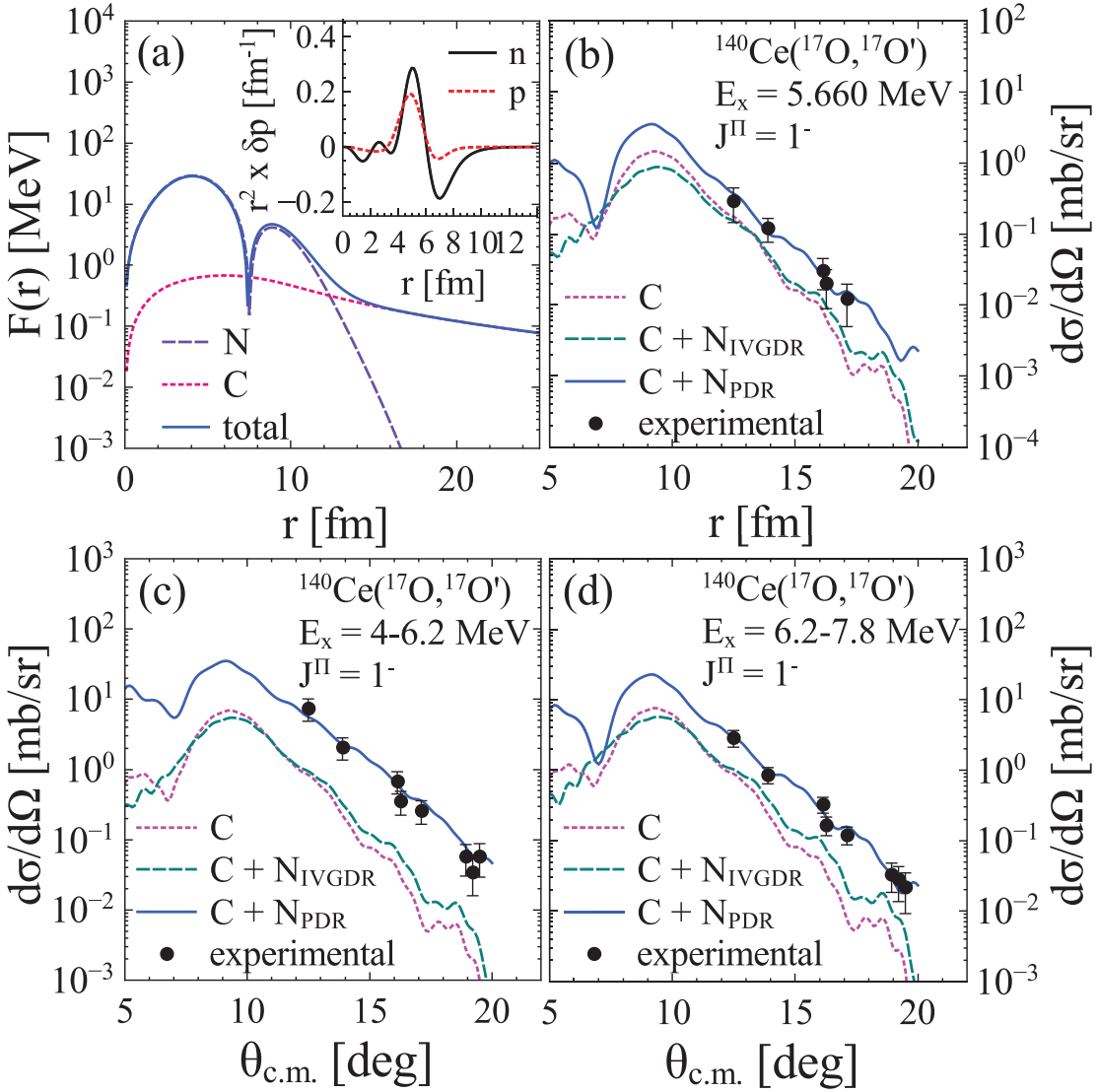
$^{90}Zr(^{17}O,^{17}O\gamma)^{90}Zr$ at 340 MeV





M. Krzysiek et al., PRC 93 (2016) 044330

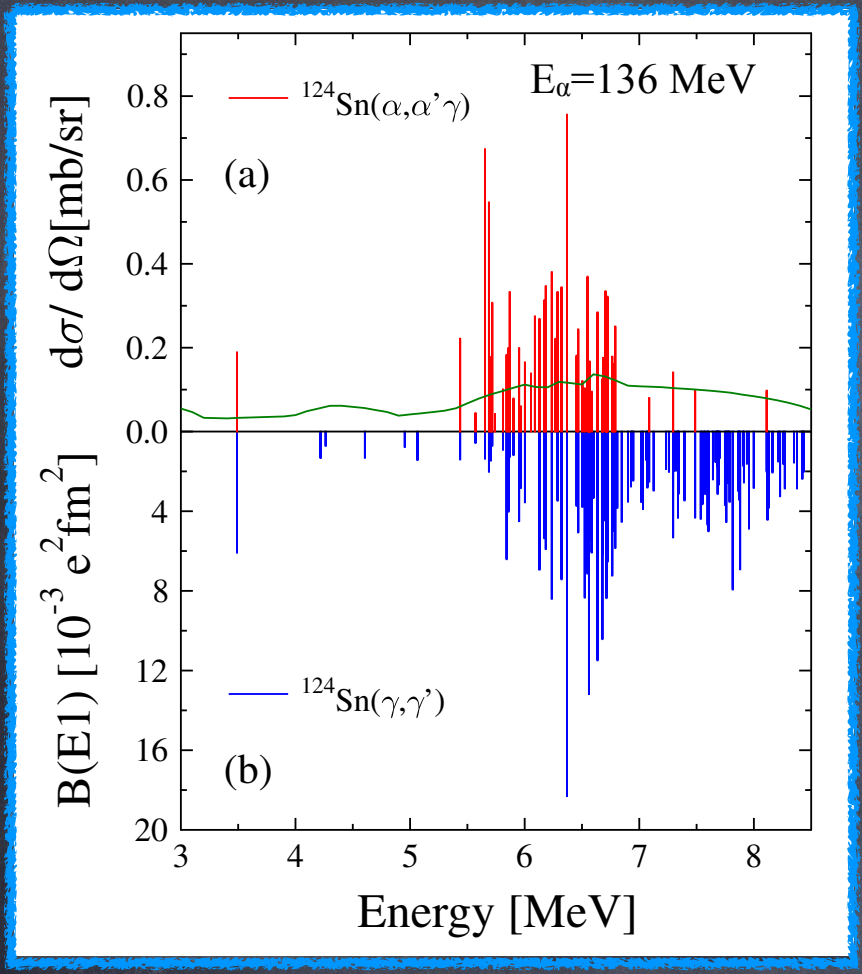
^{140}Ce(^{17}O,^{17}Oγ)^{140}Ce at 340 MeV



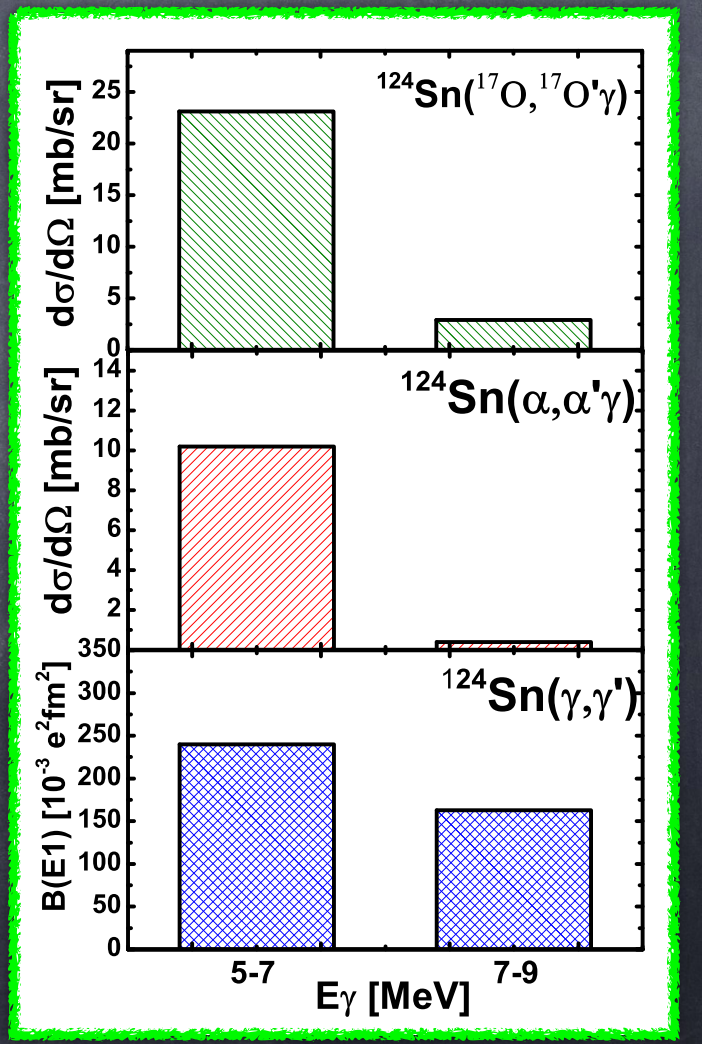
Experimental data isoscalar probe

(below neutron emission threshold)

The use of isoscalar probes has brought to light a new feature of this new mode



The splitting of the PDR



D. Savran et al., PRL 97 (2006) 172502

J. Endres et al., PRL 80(2009) 034302

J. Endres et al., PRL 105 (2010) 212503

F.C.L. Crespi et al., PRL 113 (2014) 012501

L. Pellegri et al., PLB 738 (2014) 519

F.C.L. Crespi et al., PRC 91 (2015) 024323

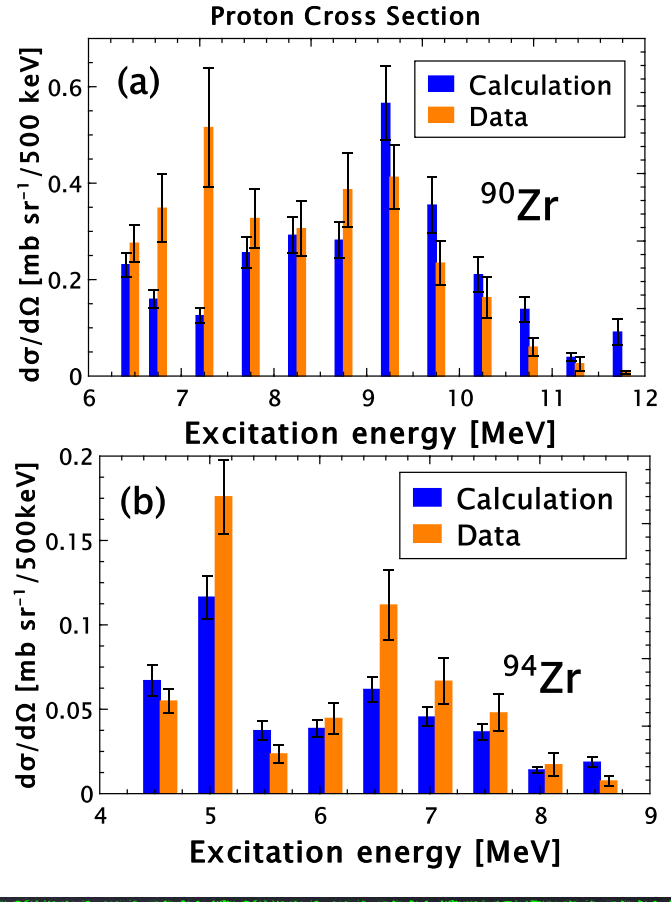
F.C.L. Crespi, et al., PLB 816 (2021) 136210

The ^{90,94}Zr nuclei investigated via (p, p′γ) at 80 MeV and (α, α′γ) at 130 MeV. At RCNP, with the magnetic spectrometer Grand Raiden for the scattered particles and the array CAGRA with HPGe detectors for the γ-decay.

The E1 ISEWSR strengths of the states were extracted from the data by DWBA calculations performed for the (α, α′γ) reaction.

Under the assumption that the information extracted with the (α, α′γ) can be extended to the (p, p′) reactions, the calculations for the cross section for the reaction (p, p′γ) have been done with the values of the ISEWSR obtained from the α reaction.

The general trend have been reproduced except for few states for the ^{90}Zr case. It is worthwhile to apply this analysis - improving the modelling - to other nuclei, to try to understand better the intrinsic structure of these low-lying dipole states.



Some Open Problems:

1. Are the dipole resonances due to collective or single-particle excitations?
2. Spherical and Deformed nuclei
3. What is the interplay between isovector and isoscalar contributions?

Eur. Phys. J. A (2015) **51**: 99
DOI 10.1140/epja/i2015-15099-6

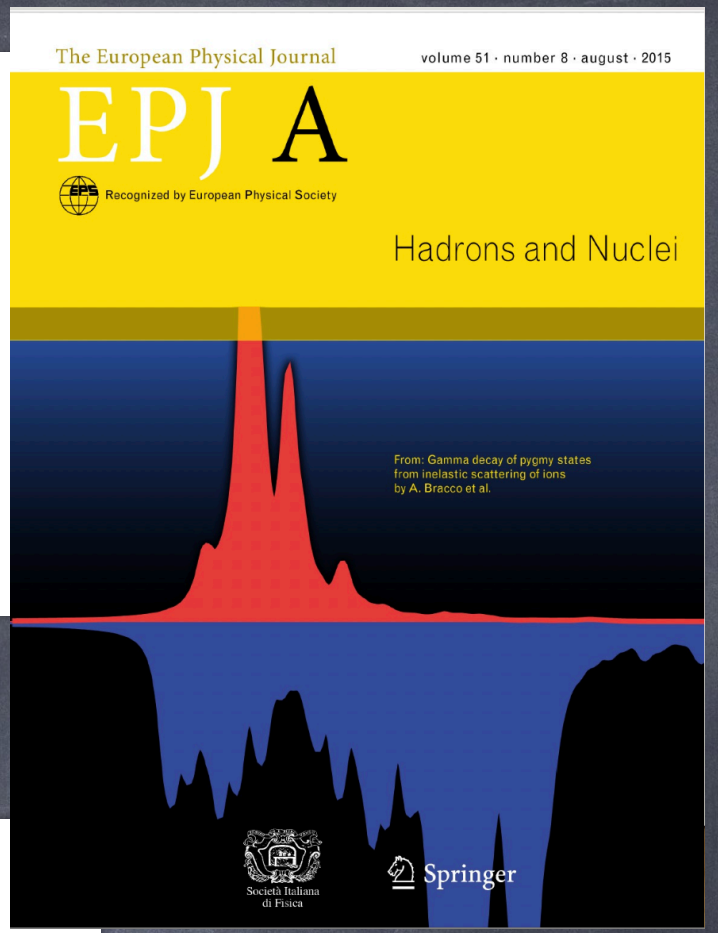
THE EUROPEAN PHYSICAL JOURNAL A

Review

Gamma decay of pygmy states from inelastic scattering of ions

A. Bracco[1,2,a], F.C.L. Crespi[1,2], and E.G. Lanza[3]

[1] Dipartimento di Fisica dell'Università degli Studi di Milano, I-20133 Milano, Italy
[2] INFN, Sezione di Milano, I-20133 Milano, Italy
[3] INFN, Sezione di Catania, I-95123 Catania, Italy



Progress in Particle and Nuclear Physics 106 (2019) 360–433

Contents lists available at ScienceDirect

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp

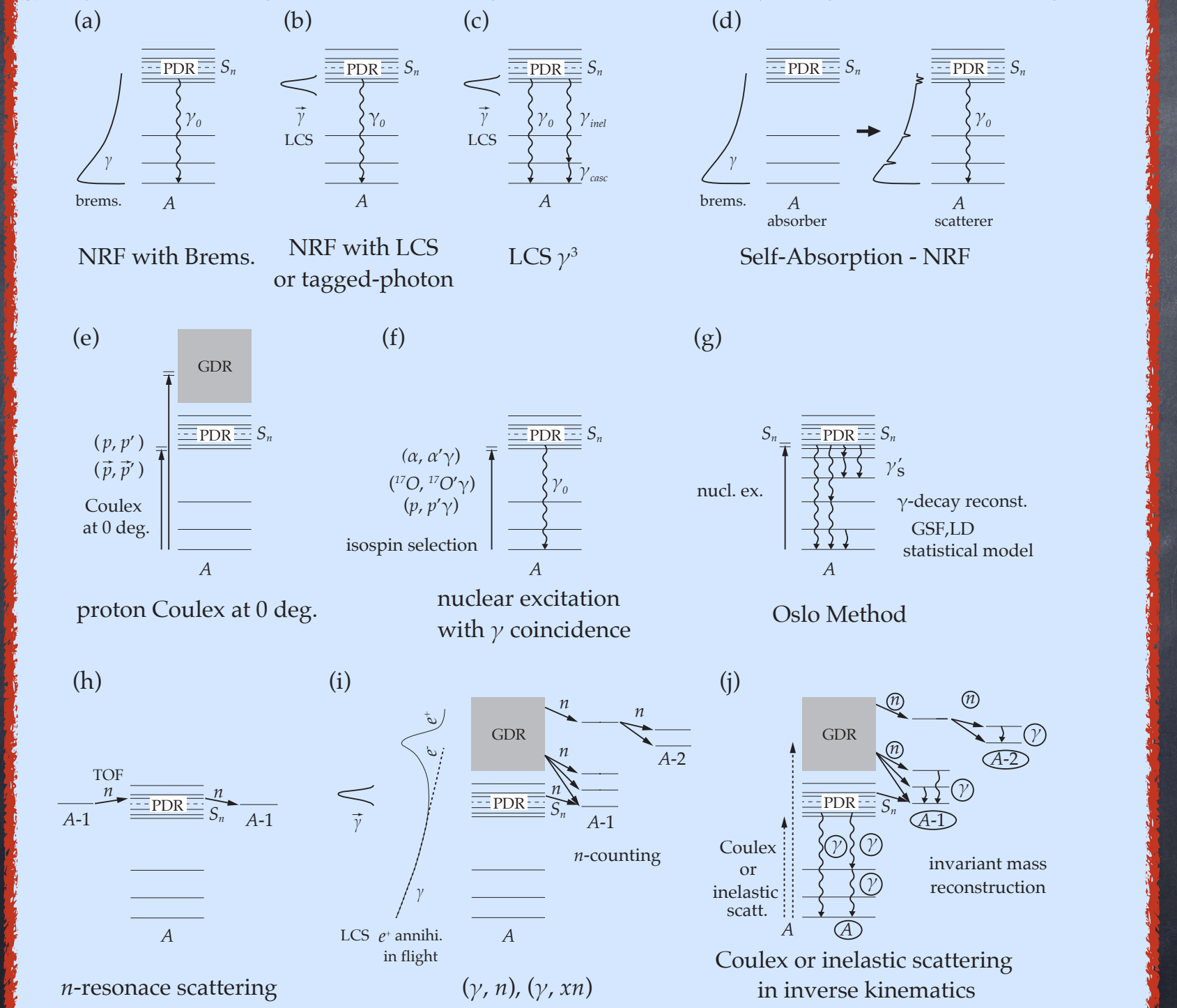
Review

Isoscalar and isovector dipole excitations: Nuclear properties from low-lying states and from the isovector giant dipole resonance

A. Bracco [a,b,*], E.G. Lanza [c], A. Tamii [d]

[a] *Dipartimento di Fisica dell'Università degli Studi di Milano, Italy*
[b] *INFN, Sezione di Milano, Italy*
[c] *INFN, Sezione di Catania, Italy*
[d] *Research Center for Nuclear Physics, Osaka University, Japan*

A. Bracco, E.G. Lanza, A. Tamii, Prog. Part. Nucl. Phys. 106 (2019) 360.




UNIVERSITÀ
degli STUDI
di CATANIA
DIPARTIMENTO DI FISICA E ASTRONOMIA
"ETTORE MAJORANA"
COMEX7


COMEX7
Catania
11-16 June 2023

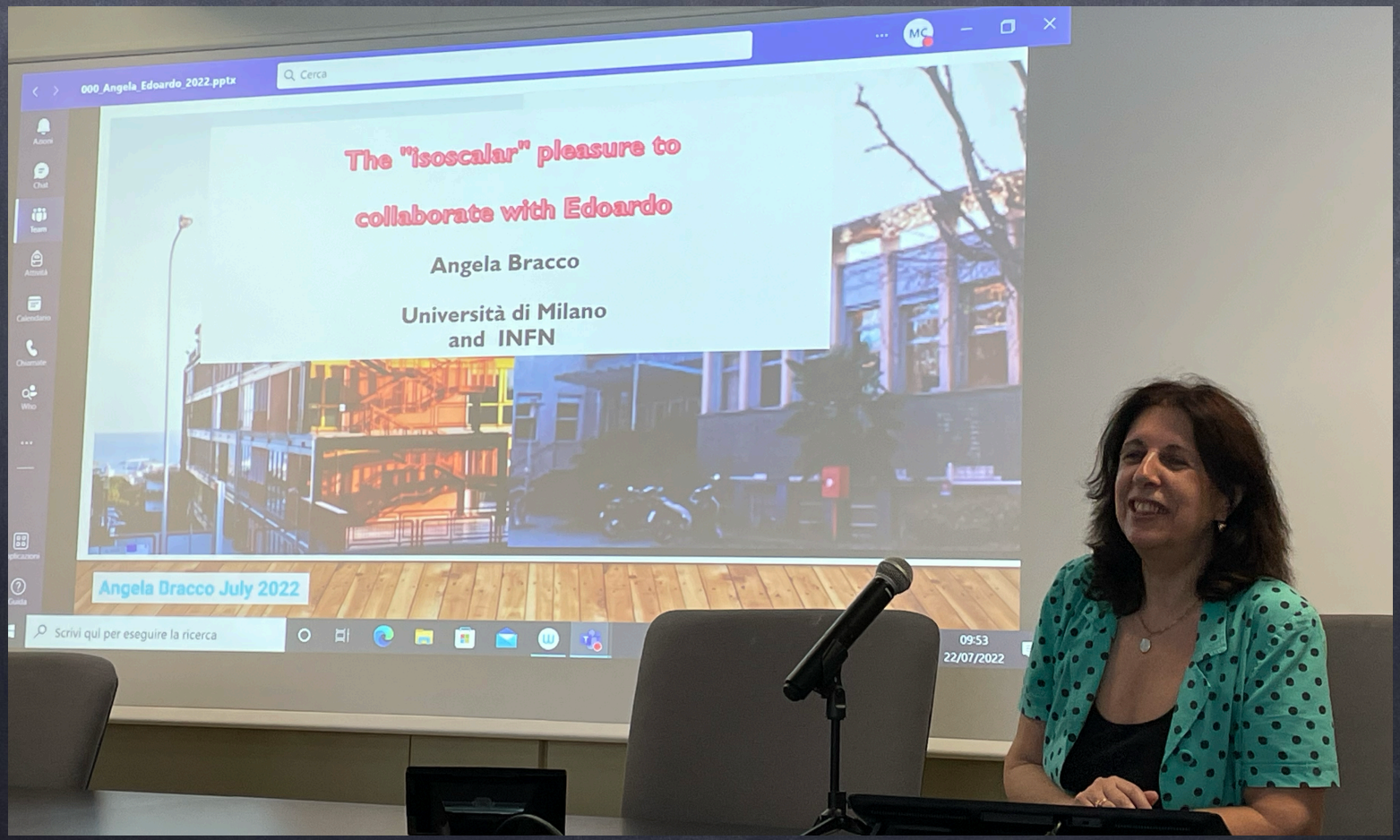

AE STVDIVM GENERALE

The title of my abstract was

The Pygmy Dipole Resonances

or

"The isoscalar pleasure to collaborate with Angela"



But this is not the end

SYMPOSIUM on Resonances and related topics

for Angela Bracco University retirement

Dear Angela,
congratulation for your past achievements
and
best wishes for the future ones!!

Thank you for your attention