COMEX5

The 5th international conference on

"COLLECTIVE MOTION IN NUCLEI UNDER EXTREME CONDITIONS"

Microscopic nuclear form factor for the Pygmy Dipole Resonance

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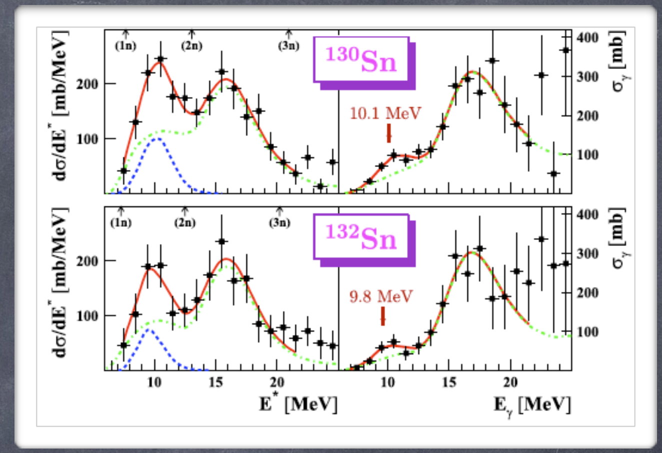
Experimental data

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

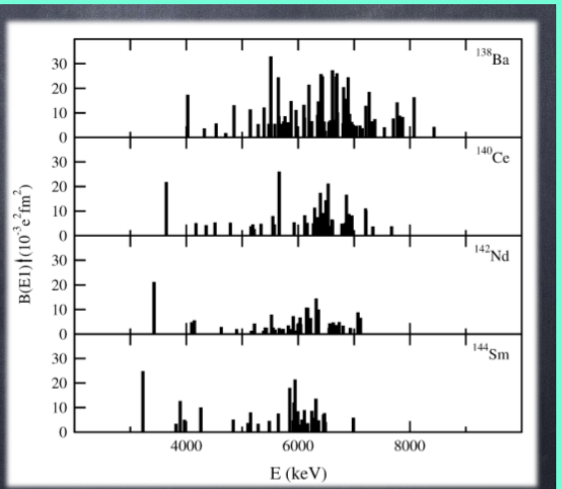


BELOW NEUTRON SEPARATION THRESHOLD

stable nuclei

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

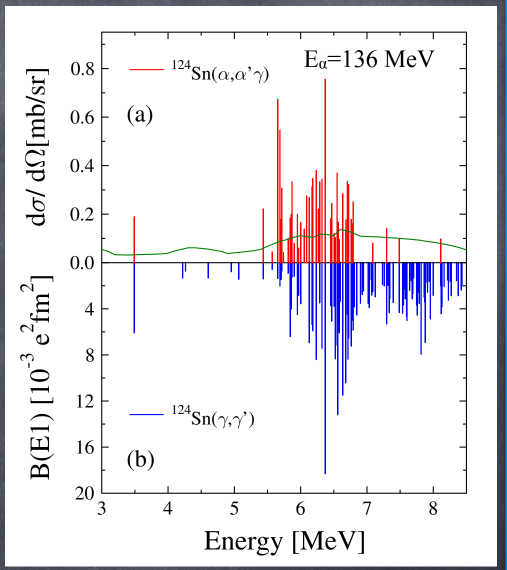


Splitting of the low-lying dipole strength

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

see also D. Negi talk on Tuesday

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



- N. Paar, D. Vretenar, E. Khan and G. Colo`, Rep. Prog. Phys. 70, 691 (2007).
- D. Savran, T. Aumann and A. Zilges, Prog. Part. Nucl. Phys. 70, 210 (2013).
- A. Bracco, F.C.L. Crespi and E.G. Lanza, Eur. Phys. J. A 51, 99 (2015).

Outline

Pygmy Dipole Resonance (PDR) can be studied with isoscalar probe, in this case the radial form factors used in the cross section calculations play an important role.

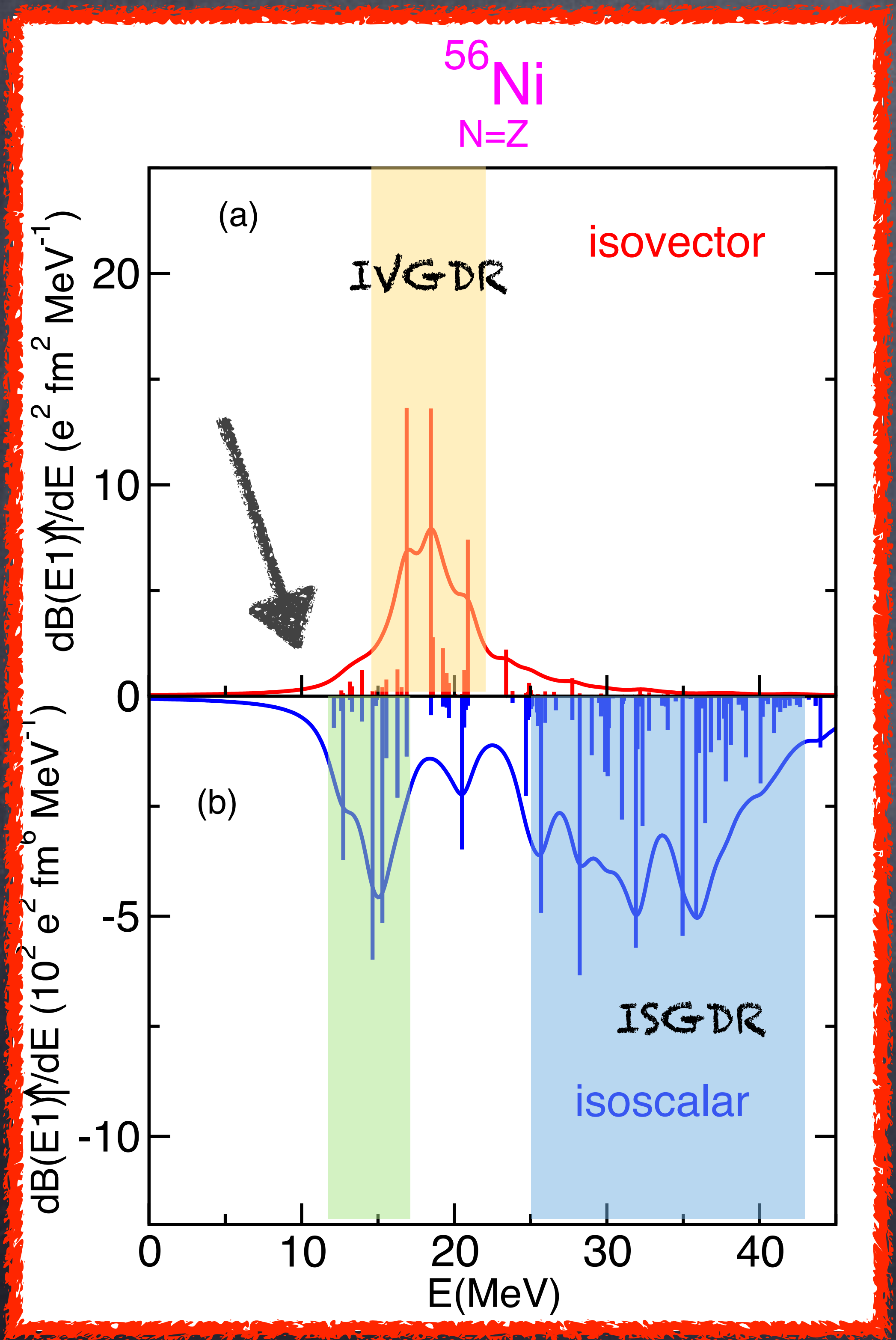
Form factors calculated within a microscopic model are compared with those provided by different macroscopic collective models.

Their differences, in the shape and magnitude, are reflected on the calculated cross section and therefore jeopardize the extracted physical quantities.

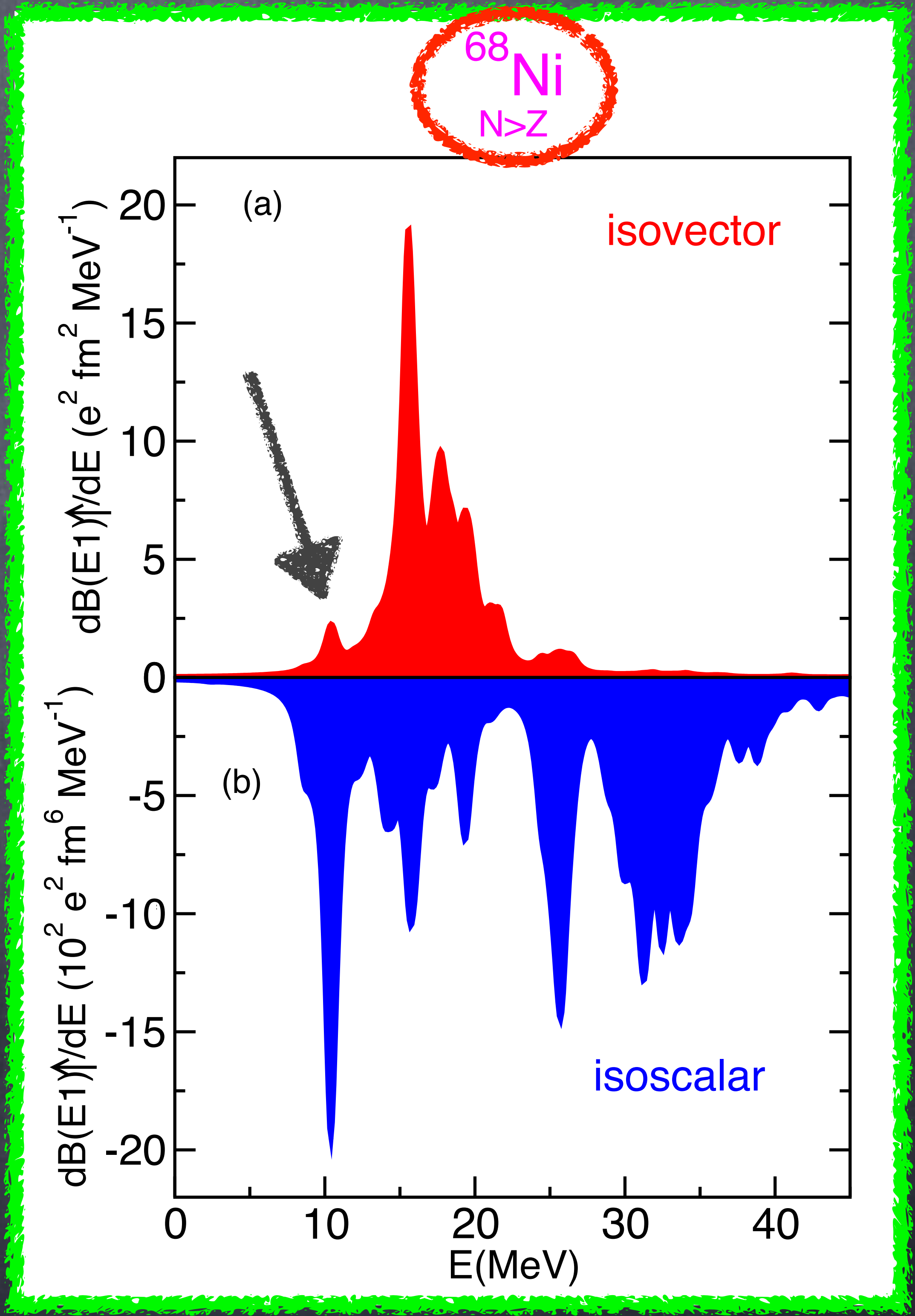
RPA calculations with SGII interaction

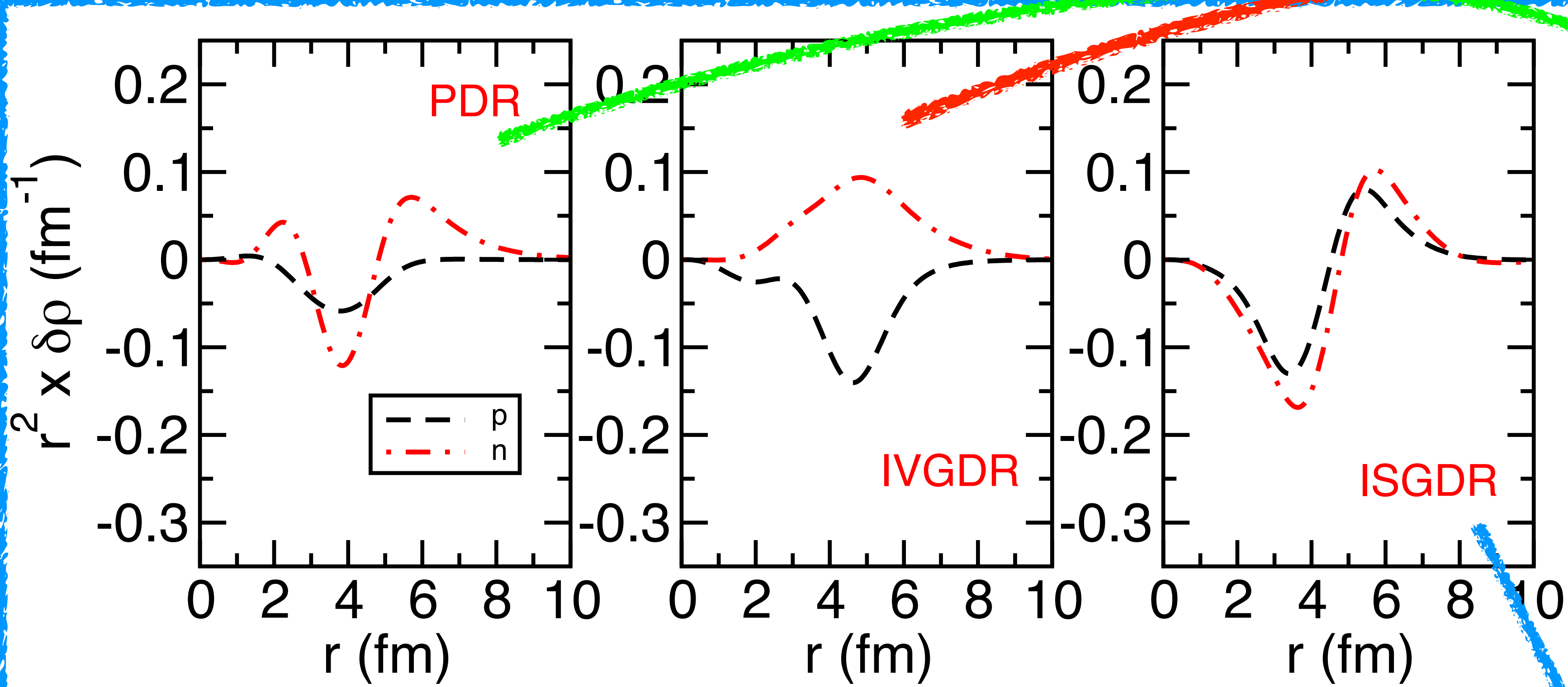
$$O_{1M}^{(IV)} = 2\frac{Z}{A}\sum_{n=1}^{N} r_n Y_{1M}(\hat{r}_n) - 2\frac{N}{A}\sum_{p=1}^{Z} r_p Y_{1M}(\hat{r}_p)$$

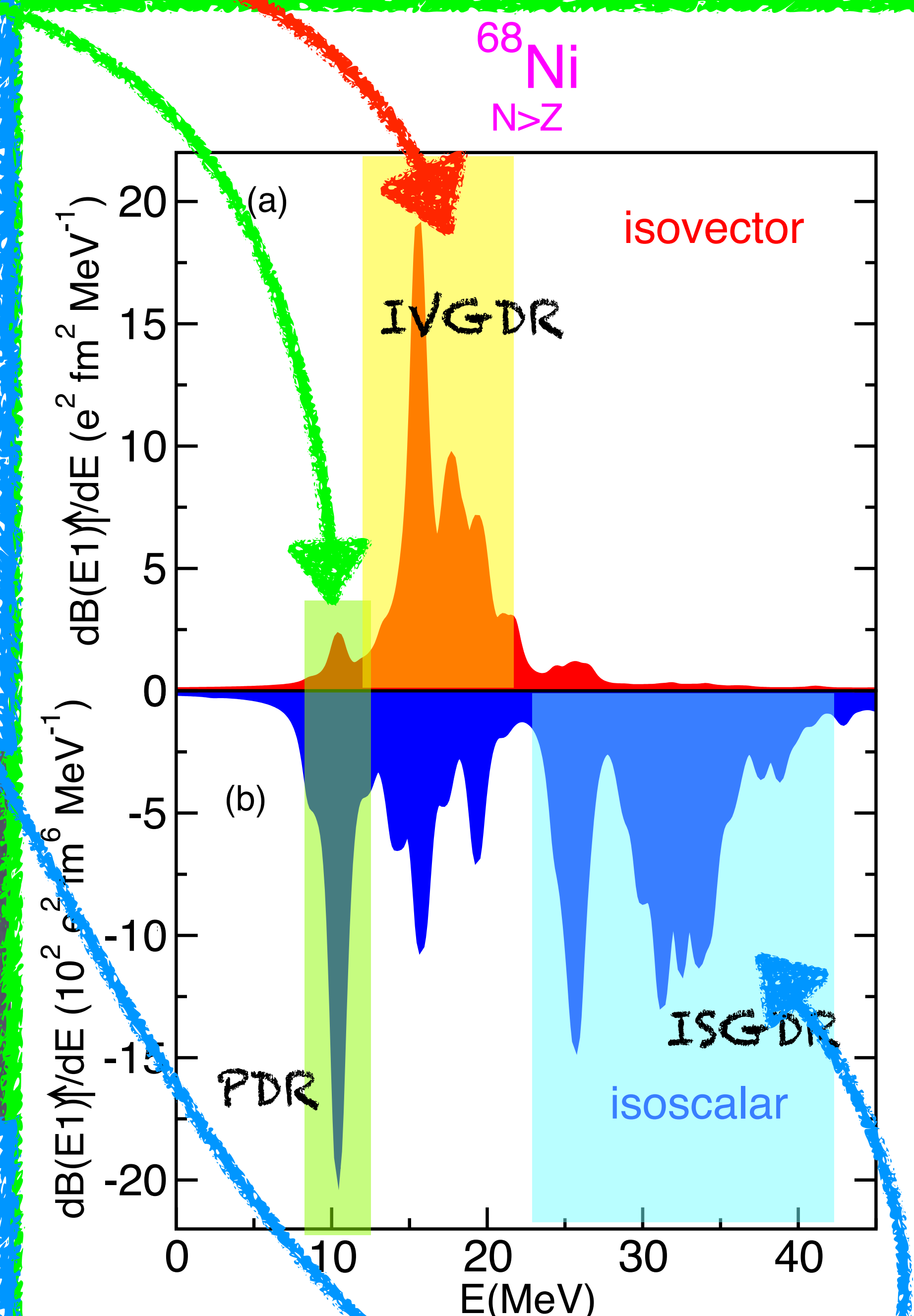
$$O_{1M}^{(IS)} = \sum_{i=1}^{A}(r_i^3 - \frac{5}{3} < r^2 > r_i) Y_{1M}(\hat{r}_i)$$



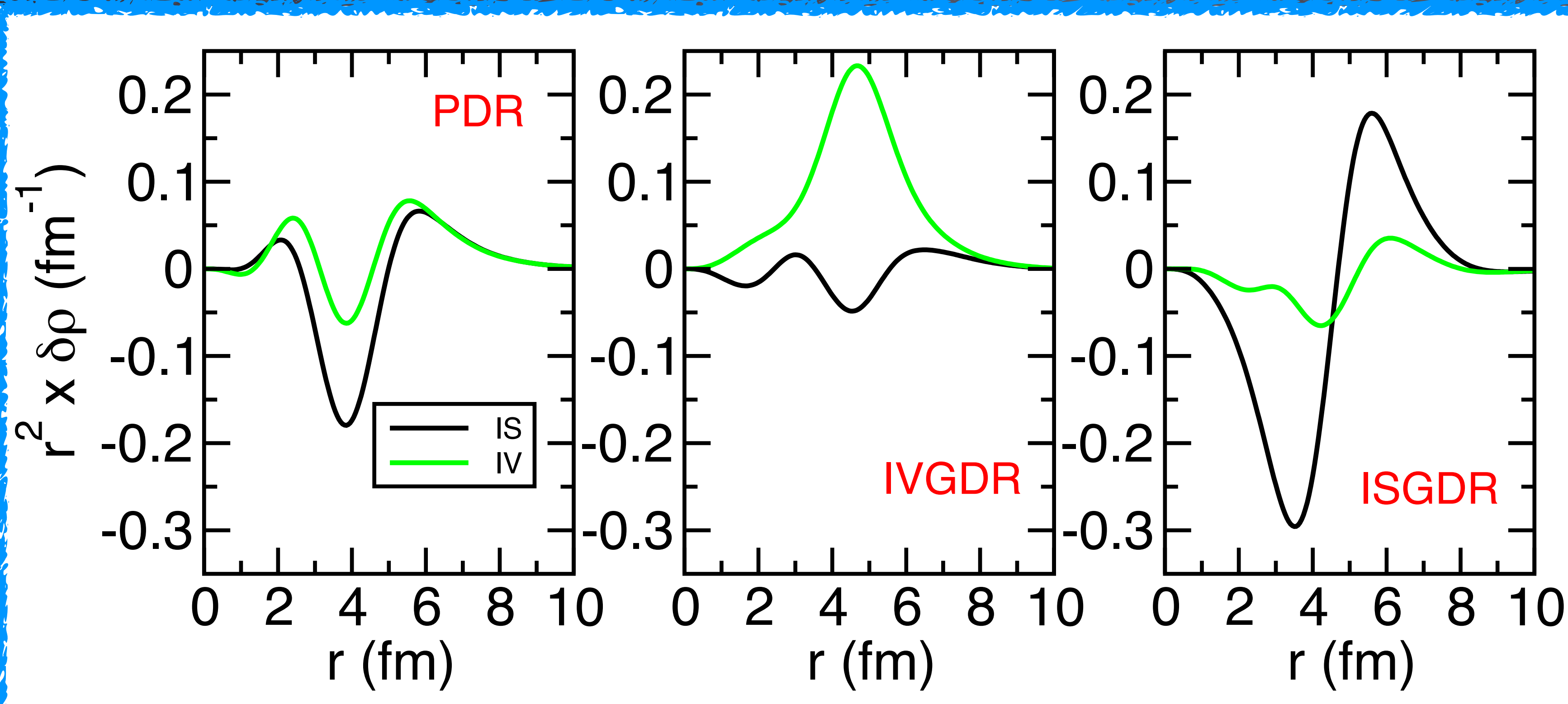
Dipole states







$$\delta\rho^{\nu} = \frac{1}{\sqrt{4\pi}} \sum_{ph} (-)^{j_p + l_p + \frac{1}{2}} \frac{\hat{j}_p \hat{j}_h}{\hat{\lambda}} < j_h \, \tfrac{1}{2} \, j_p \, -\tfrac{1}{2} \,|\, \lambda 0 > \delta(\lambda + l_p + l_h, even)$$
$$\cdot \left[X^{\nu}_{ph} - Y^{\nu}_{ph} \right] R_{l_p j_p}(r) R_{l_h j_h}(r)$$



This is a $3\hbar\omega$ nuclear transitions generated by the second order $\Delta L=1$ transition operator and it can be seen as a compressional mode.

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

Then these states can be studied and have been studied also with reactions where the nuclear part of the interaction is involved.

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 effects, they can be derived in macroscopic or microscopic approaches

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

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

Dipole radial form factors calculation

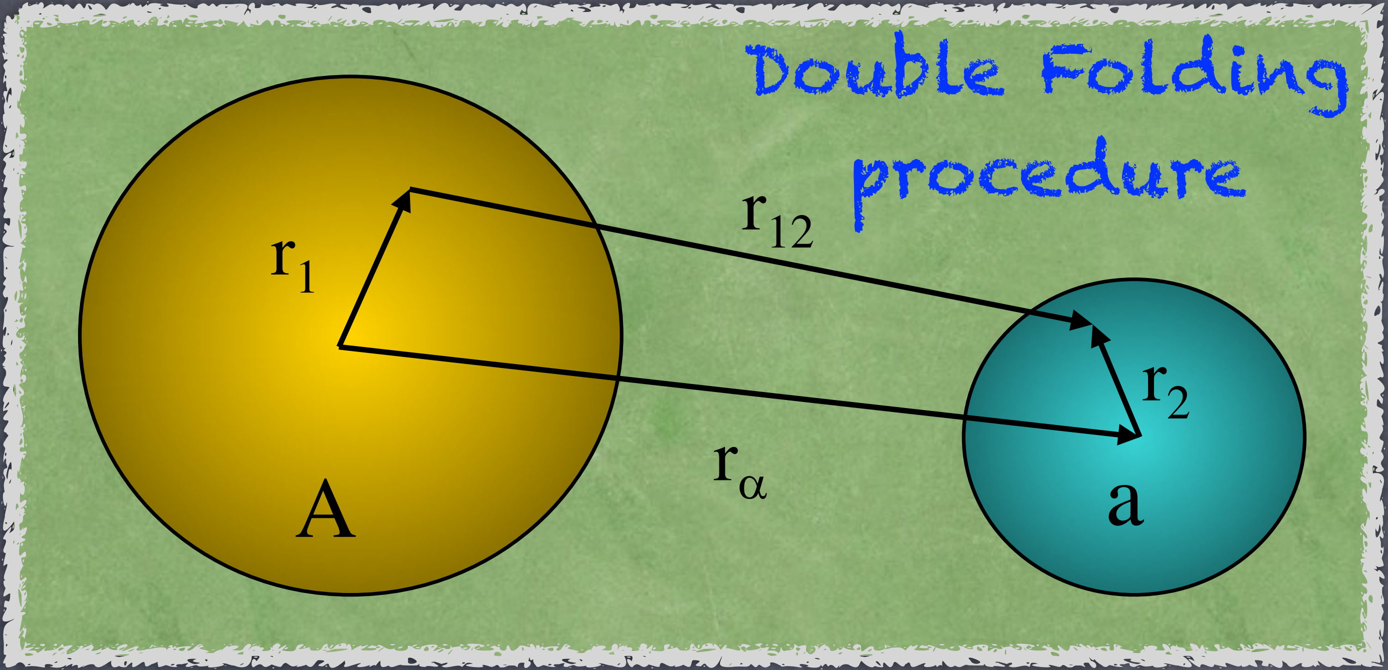
- Goldhaber-Teller for the IVGDR
- Harakeh-Dieperink for the ISGDR
- Microscopic form factor (double folding)

Double folding potential

v_0 nucleon-nucleon potential

$$\boxed{U_0(\vec{r}_\alpha) = \iint \rho_A(\vec{r}_1)\, v_0(r_{12})\, \rho_a(\vec{r}_2)\, d\vec{r}_1\, d\vec{r}_2}$$

$$r_{12} = |\vec{r}_\alpha + \vec{r}_2 - \vec{r}_1|$$



The nuclear form factors

$$F(r_\alpha) = \int\int [\delta\rho_{A_n}(r_1) + \delta\rho_{A_p}(r_1)] \times$$
$$v_0(r_{12})[\rho_{a_n}(r_2) + \rho_{a_p}(r_2)] r_1^2 dr_1 r_2^2 dr_2$$

The transition densities $\delta\rho$ can be calculated in a macroscopic or microscopic way

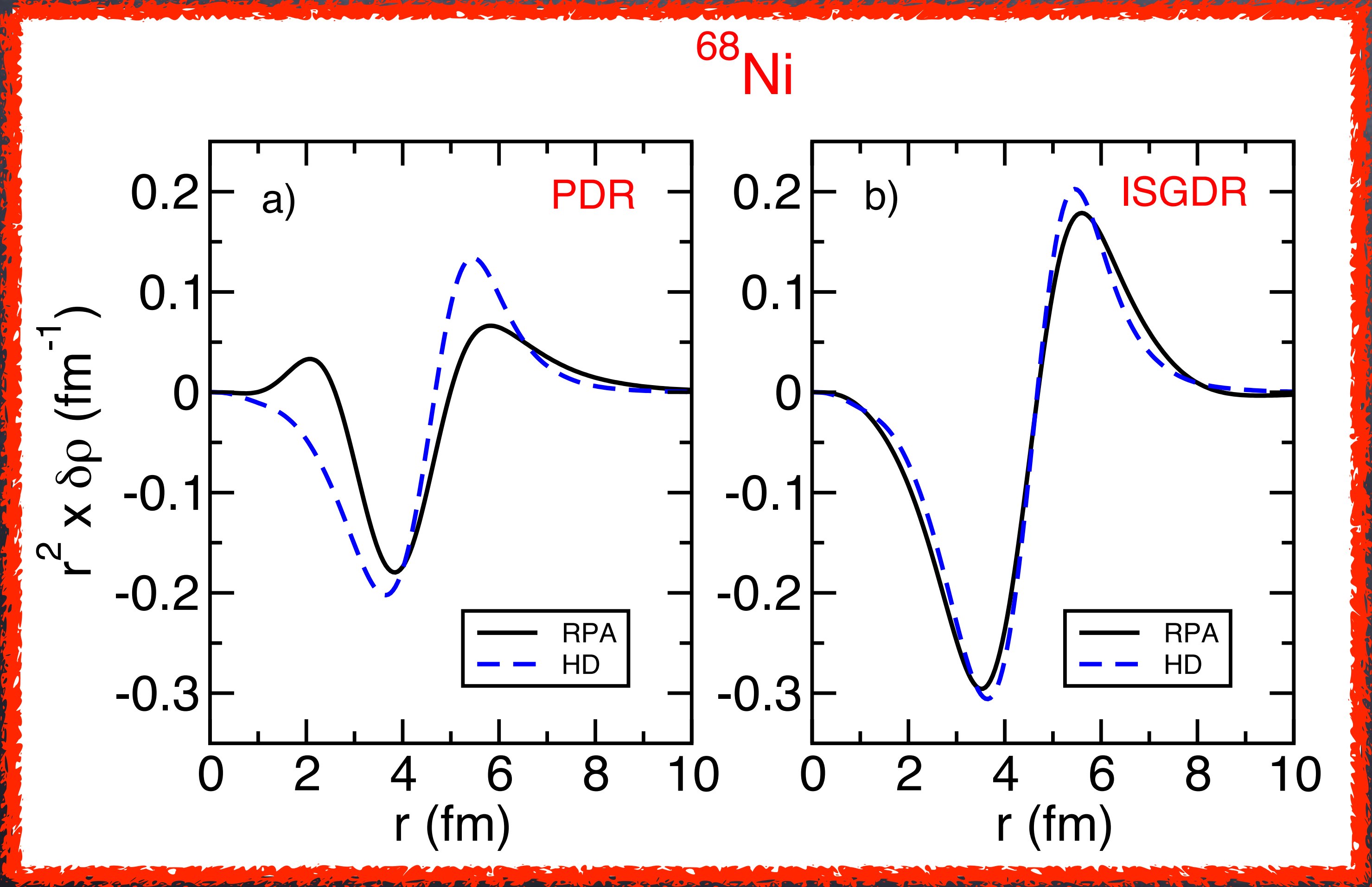
T. J. Deal, NPA 217 (1973) 210;
M. N. Harakeh and A. E. L. Dieperink PRC 23 (1981) 2329

Macroscopic transition density for the ISGDR

$$\rho^1(r) = -\frac{\beta_1}{R\sqrt{3}}\left[10r + (3r^2 - \frac{5}{3} < r^2 >)\frac{d}{dr})\right]\rho_0(r)$$

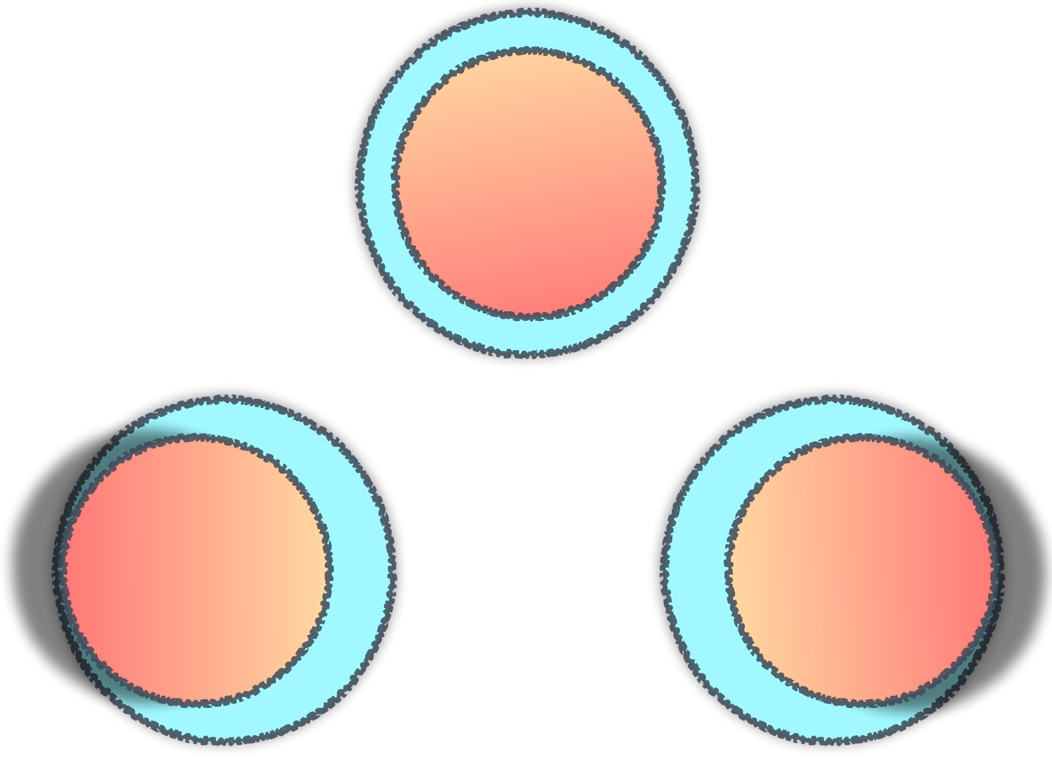
$$\beta_1^2 = -\left(\frac{6\pi\hbar^2}{mAE_x}\right)\frac{R^2}{11 < r^4 > -\frac{25}{3} < r^2 >^2}$$

R is the half-density radius of the mass distribution.



For both states, the macroscopic transition density has been scaled according to the following condition

$$\int_0^\infty \rho^1_{RPA}(r)\, r^5\, dr = \int_0^\infty \rho^1_{macro}(r)\, r^5\, dr$$



$$\Delta x_S = -x\frac{Z+N_C}{A} \quad ; \quad \Delta x_C = x\frac{N_S}{A}$$

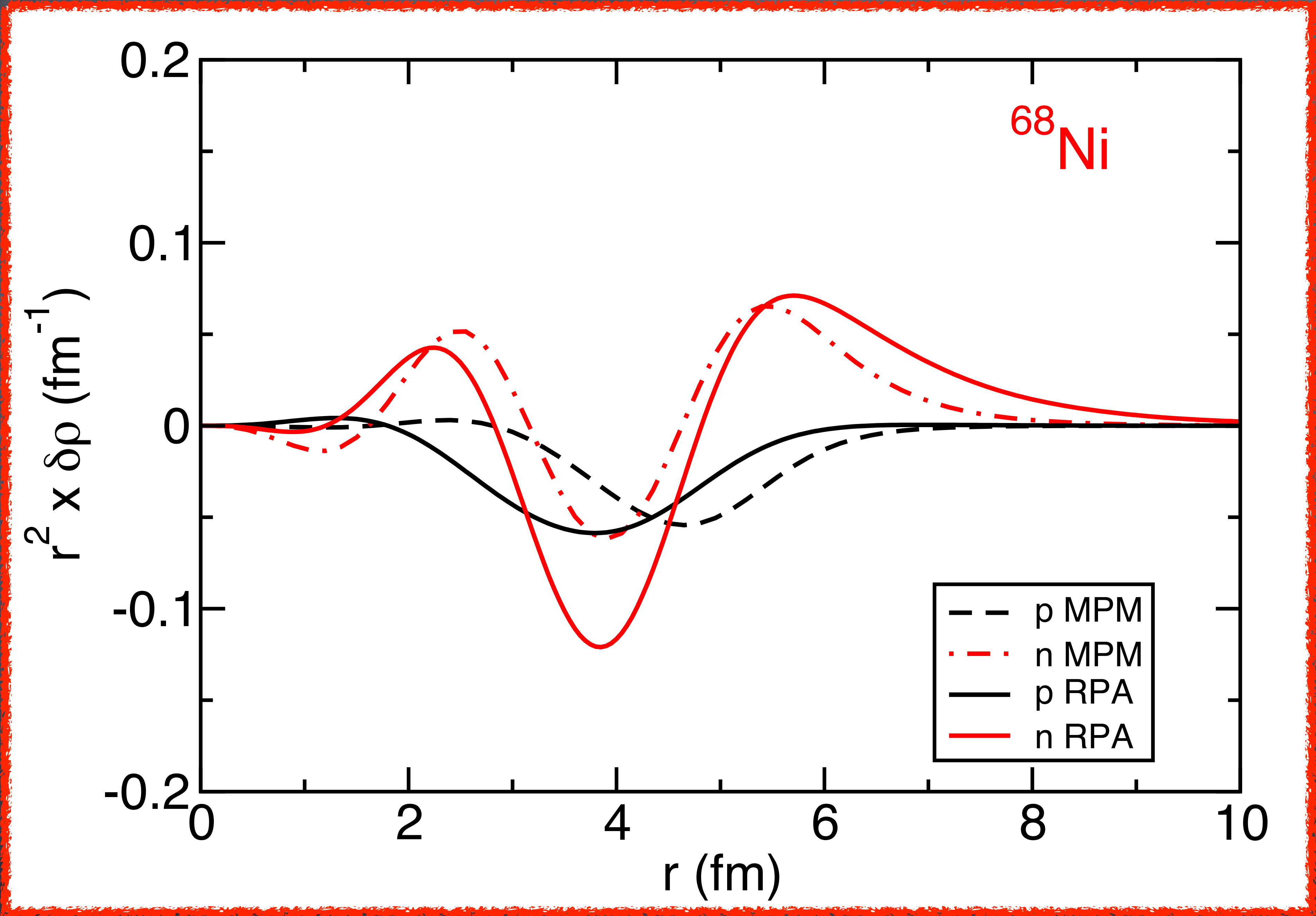
$$\rho(r) = \rho_p(r) + \rho_n^C(r) + \rho_n^S(r)$$

$$\delta\rho_n = \beta\left(\frac{N_S}{A}\frac{d}{dr}\rho_n^C - \frac{Z+N_C}{A}\frac{d}{dr}\rho_n^S\right)$$

$$\delta\rho_p = \beta\frac{N_S}{A}\frac{d}{dr}\rho_p$$

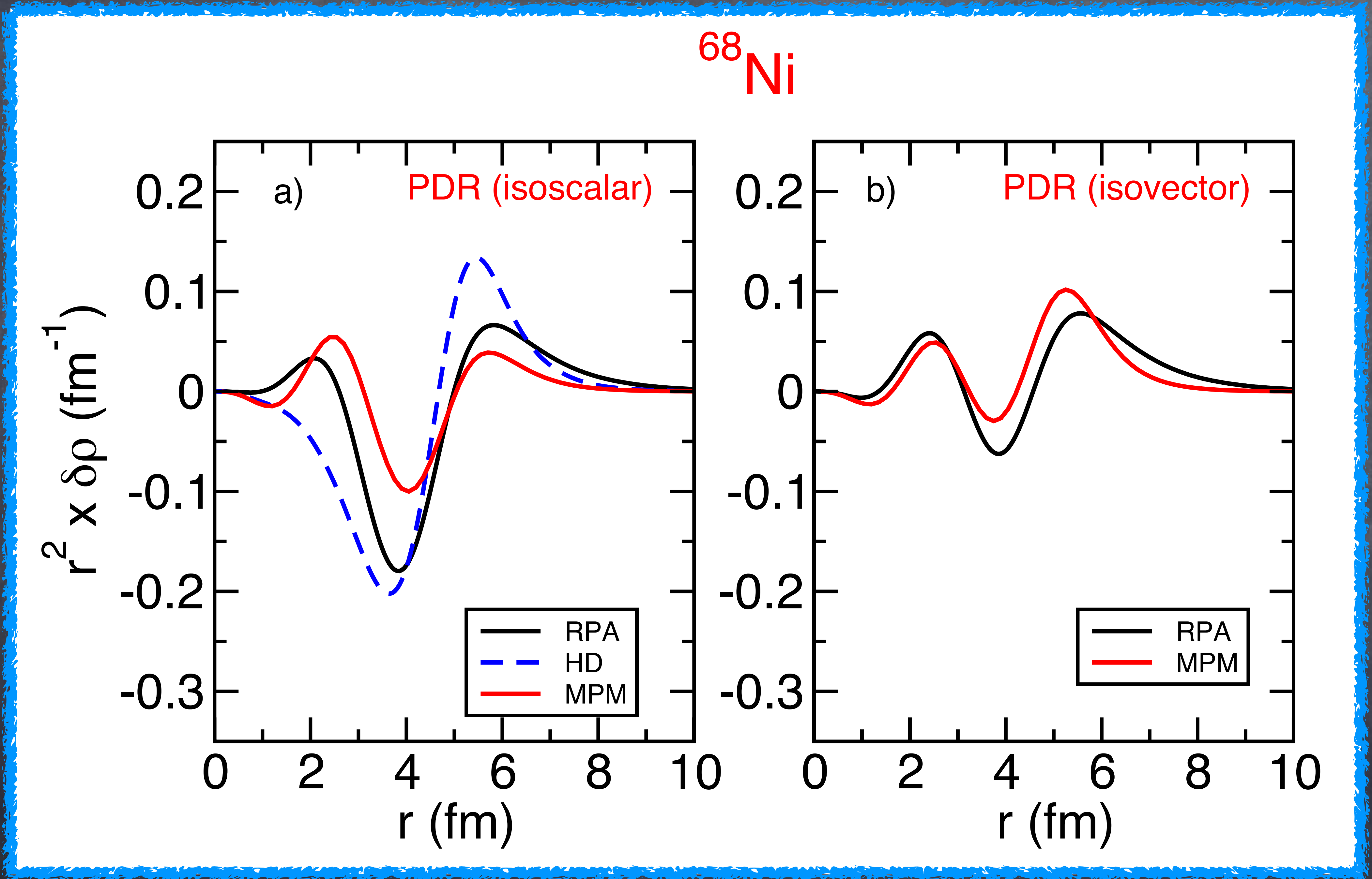
$$\delta\rho_{isosc} = \beta\left(\frac{N_S}{A}\frac{d}{dr}\left(\rho_n^C + \rho_p\right) - \frac{Z+N_C}{A}\frac{d}{dr}\rho_n^S\right)$$

$$\delta\rho_{isov} = \beta\left(\frac{N_S}{A}\frac{d}{dr}\left(\rho_n^C - \rho_p\right) - \frac{Z+N_C}{A}\frac{d}{dr}\rho_n^S\right)$$

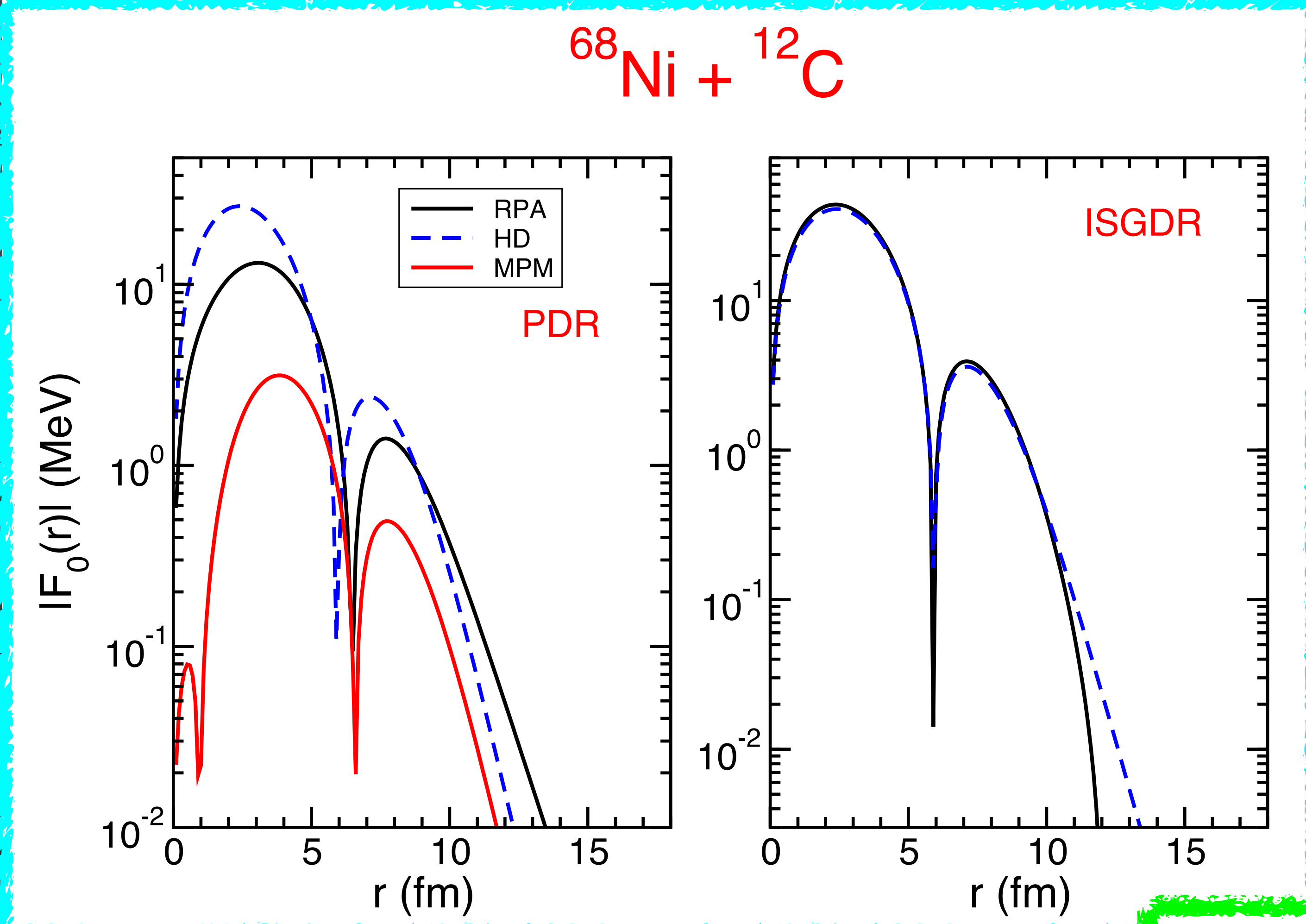


68Ni
p MPM
n MPM
p RPA
n RPA
r (fm)
r2 x δρ (fm-1)
0.2
0.1
0
-0.1
-0.2
0
2
4
6
8
10

We compare the RPA isoscalar transition densities with the two macroscopic model.



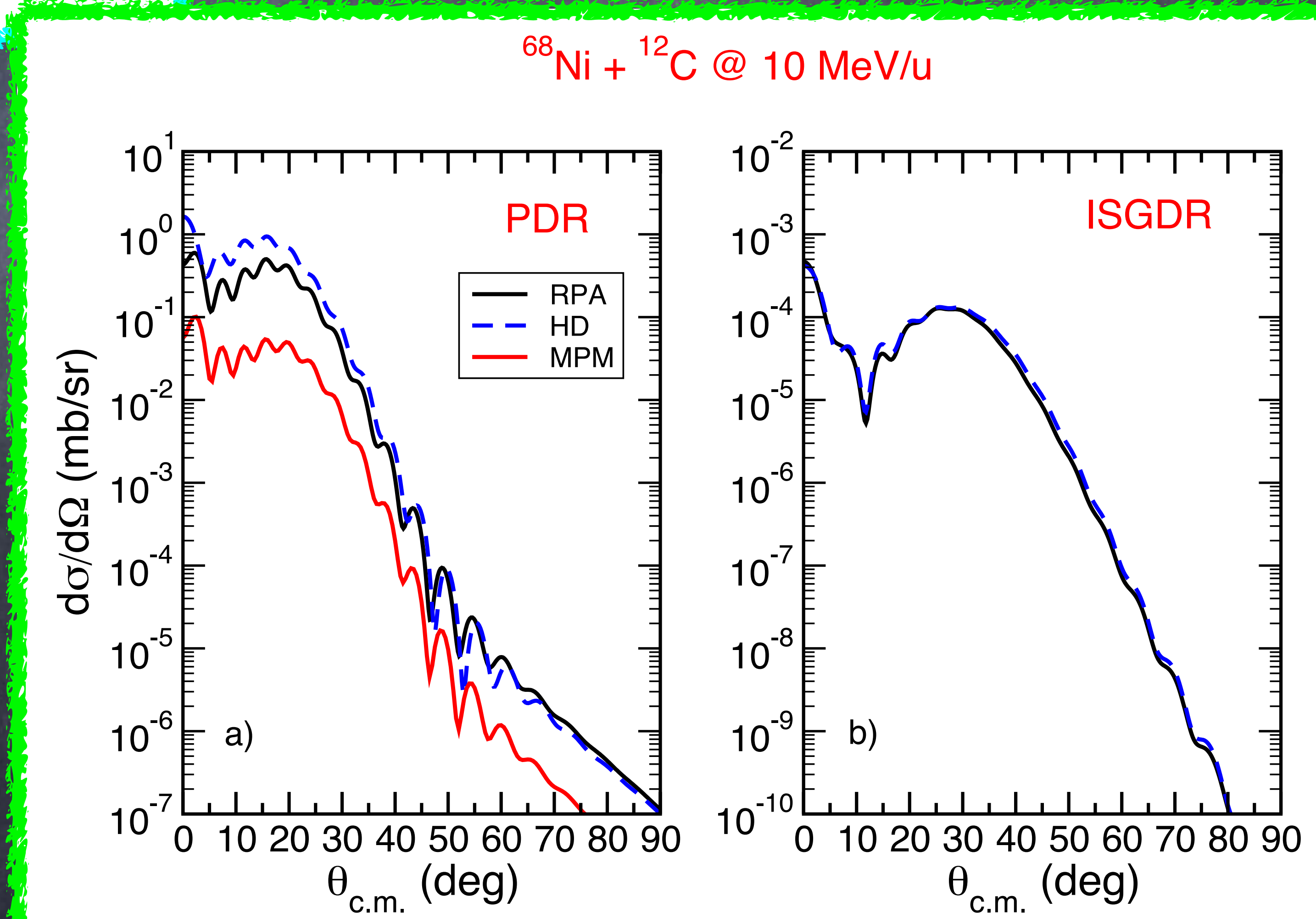
In both the macroscopic transition densities, the RPA ground state density has been used.



E.G. Lanza, A. Vitturi and M.V. Andrés, PRC 91, 054607 (2015)

The form factors have been obtained with the double folding procedure with the M3Y nucleon-nucleon potential and with the micro (RPA) and macro transition densities

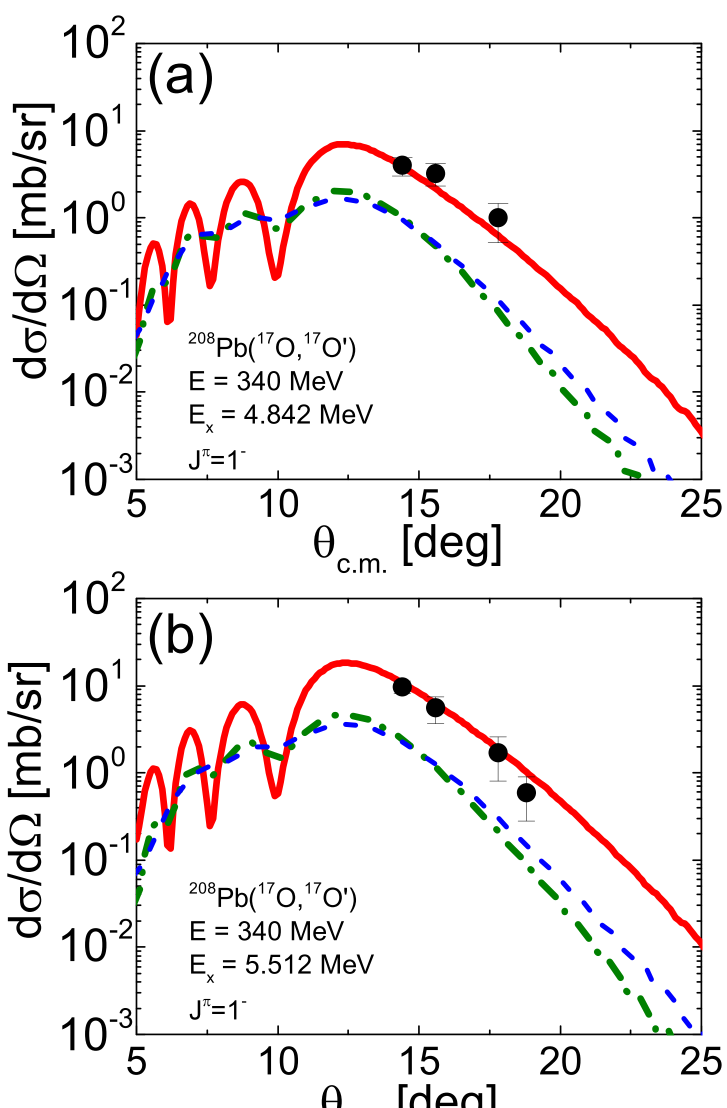
DWBA calculations done with the DWUCK4 code

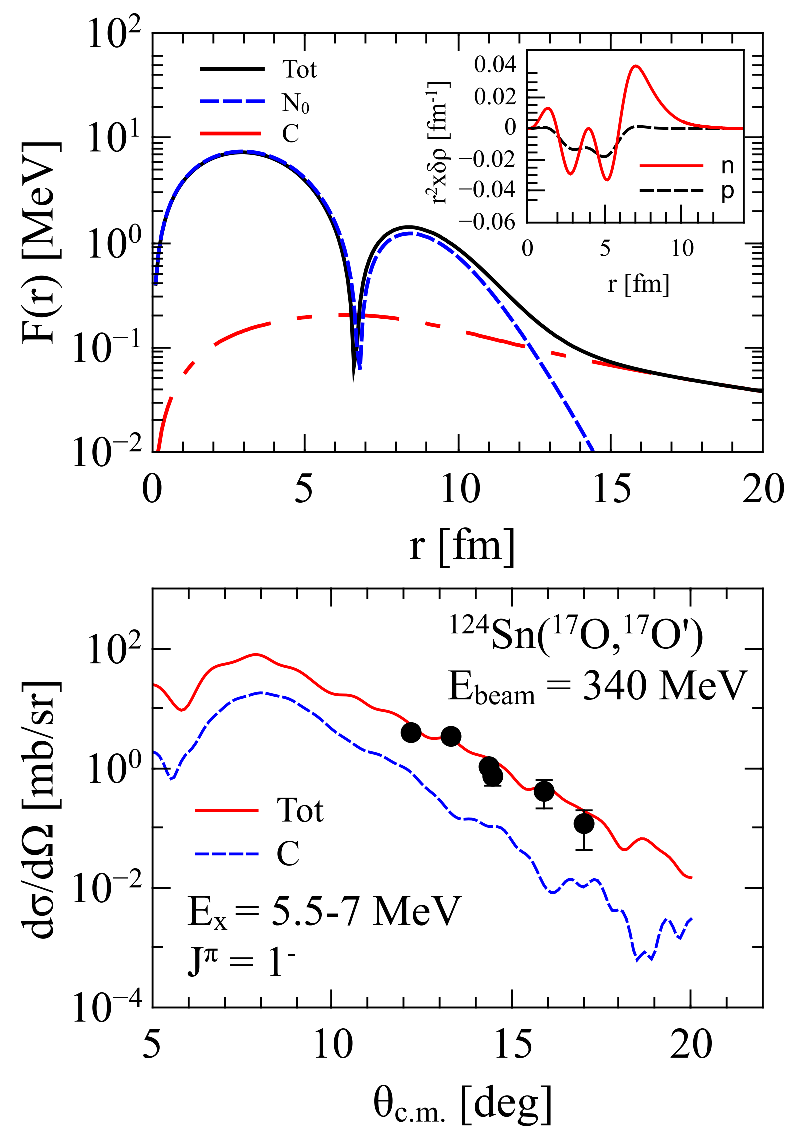


F.C.L. Crespi et al.,
PRL 113 (2014) 012501

$^{208}Pb(^{17}O,^{17}O\gamma)^{208}Pb$
at 340 MeV

Using TRACE prototype and AGATA Demonstrator system



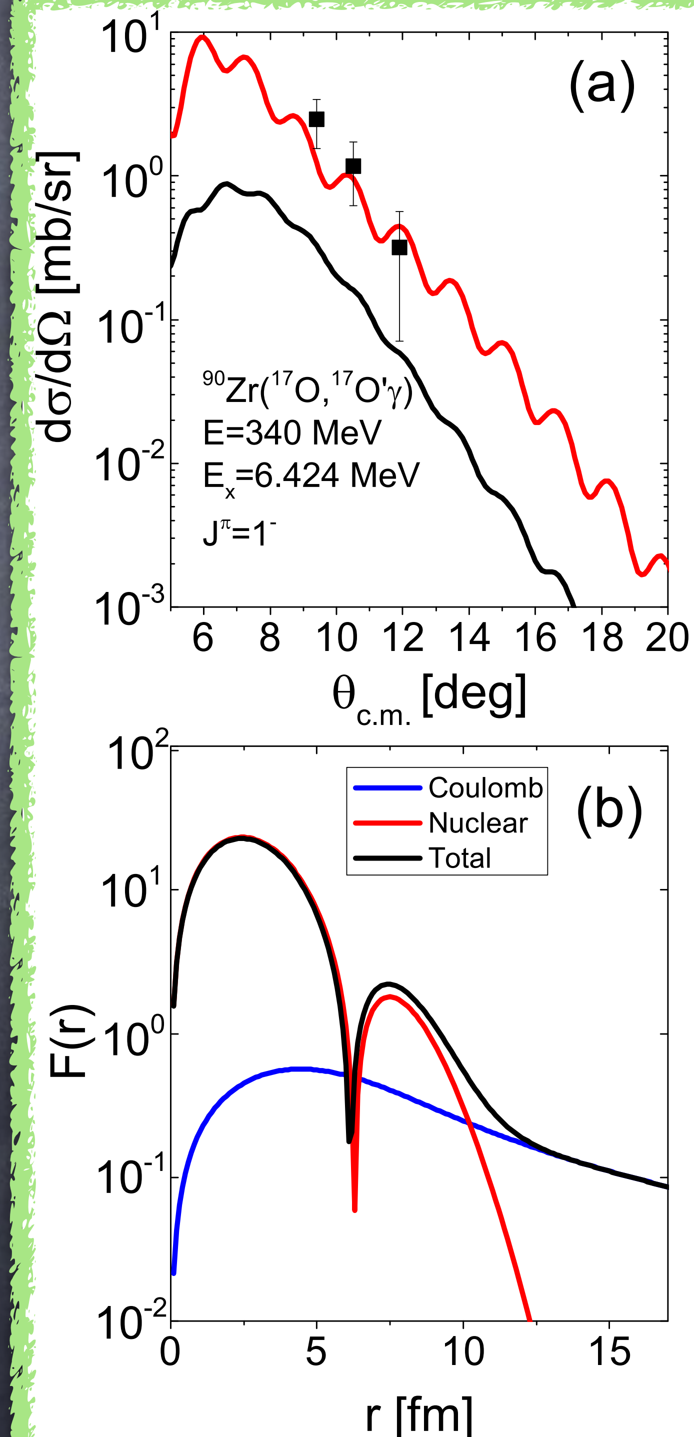


L. Pellegri et al.,
PLB 738 (2014) 519

$^{124}Sn(^{17}O,^{17}O\gamma)^{124}Sn$
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



Summary

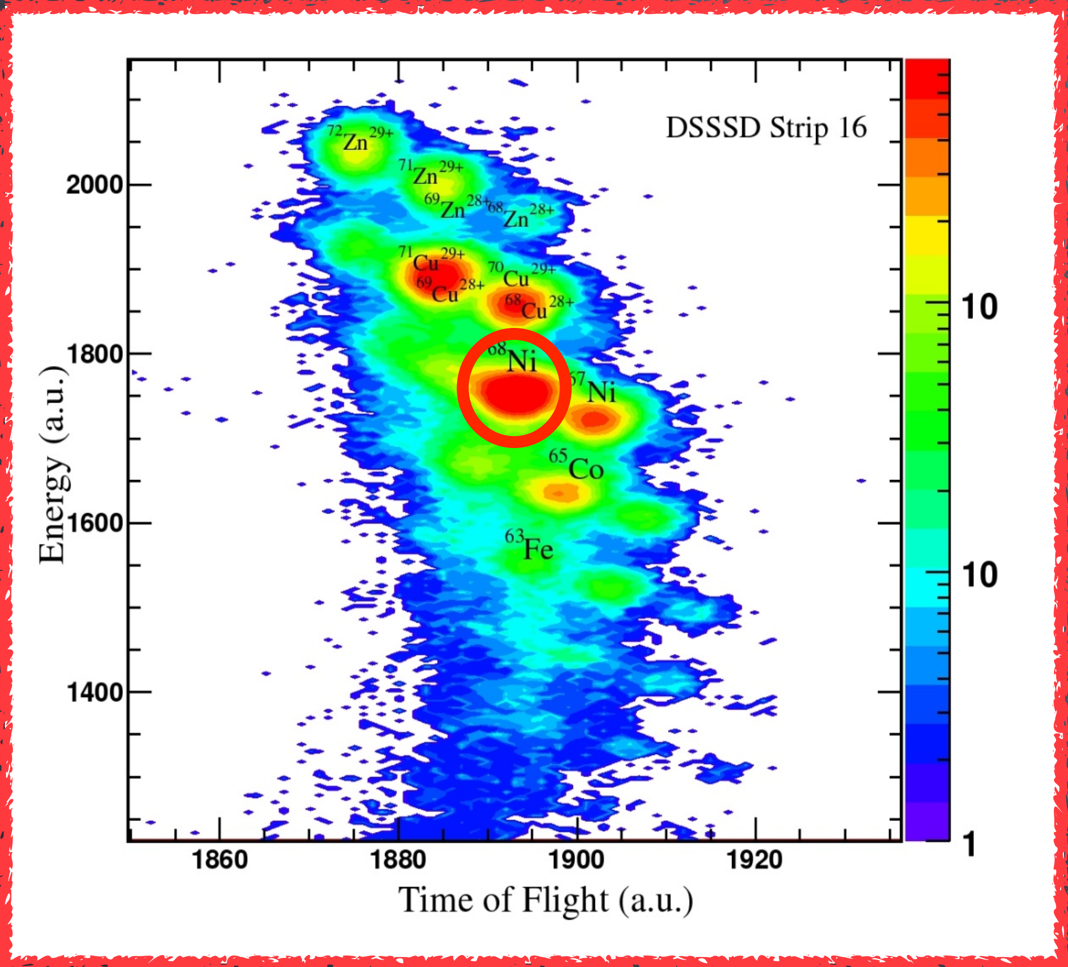
For the study of the Pygmy Dipole Resonance with isoscalar probe, the form factors calculated within a microscopic model are compared with those provided by different macroscopic collective models.

Their differences, shown in the shape and magnitude, are reflected on the calculated cross section and therefore jeopardize the extracted physical quantities.

For the PDR states, it is of paramount importance the use of a microscopic radial form factor

Experiment with CHIMERA at LNS (end of November)

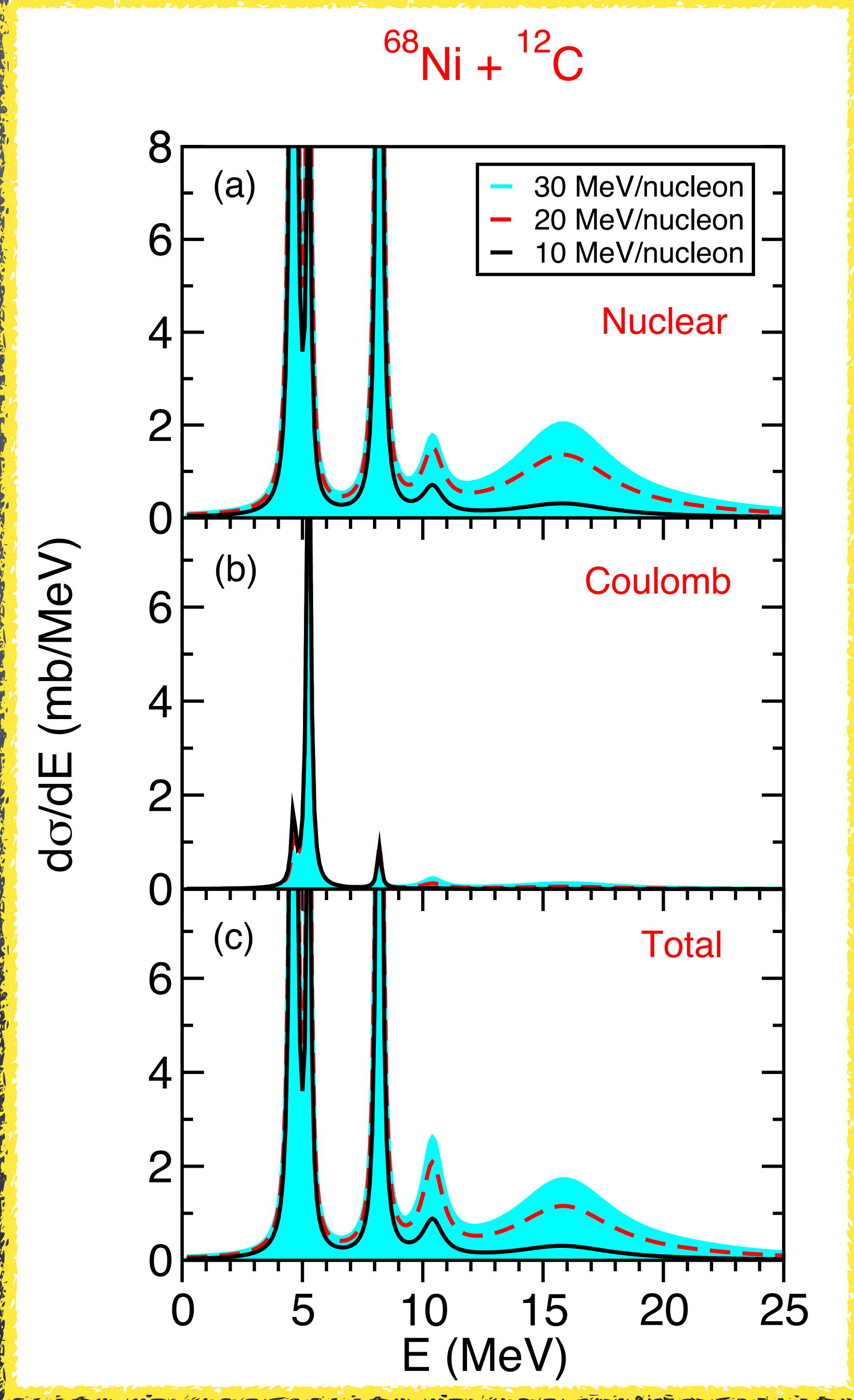
At LNS a primary ^{70}Zn beam of 40 MeV/A on a ^{9}Be target produce a secondary ^{68}Ni beam in the CHIMERA hall. A yield of 20kHz was measured for this beam.



$^{68}Ni + ^{12}C$

@

30 A·MeV



We propose to use this beam at energy around 30 A·MeV on a thick ^{12}C target to excite the pygmy resonance. The γ-decay of the resonance can be measured using the CsI of the CHIMERA detector.

Thank you for your attention