Collectivity of pygmy resonance in spherical Ni isotopes and deformed Fe nucleus

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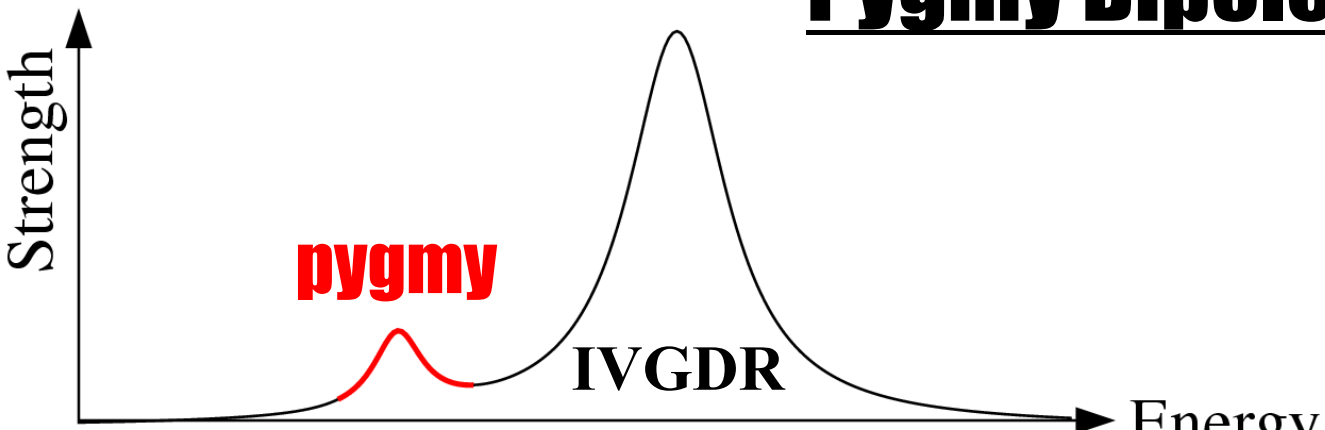
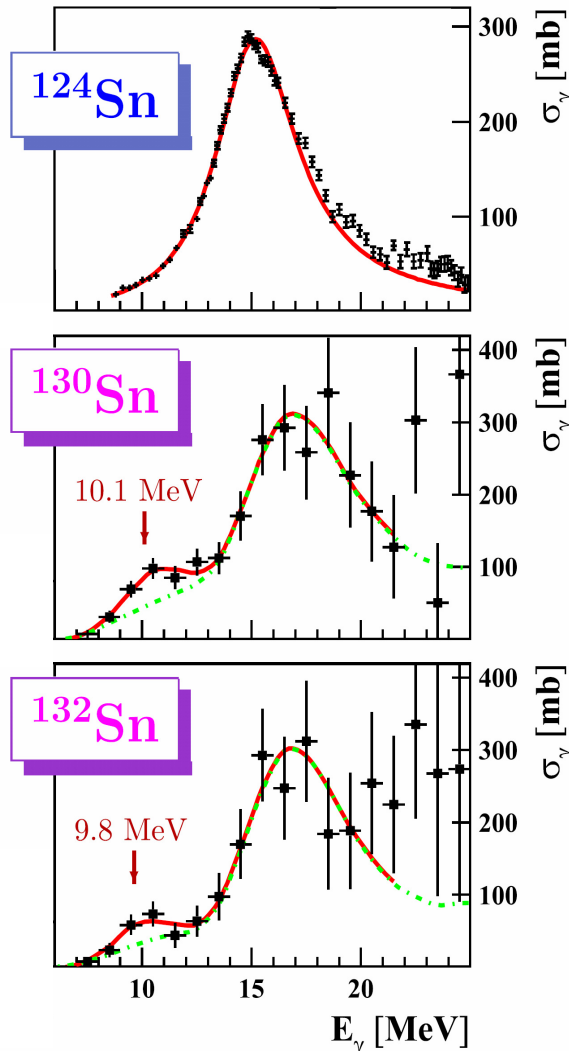
Pygmy Dipole Resonance





Z=50

130, 132Sn: P. Adrich et al., PRL 95, 132501.

N=82

140Ce: R.-D. Herzberg et al., PLB390, 49.

138Ba: R.-D. Herzberg et al., PRC60, 051307.

138Ba, **140Ce**, **144Sm**: A. Zilges et al., PLB542, 43.

Z=82

208Pb: N. Ryezayeva et al., PRL 89, 272502.

204, 206-208Pb: J. Enders et al., NPA724, 243.

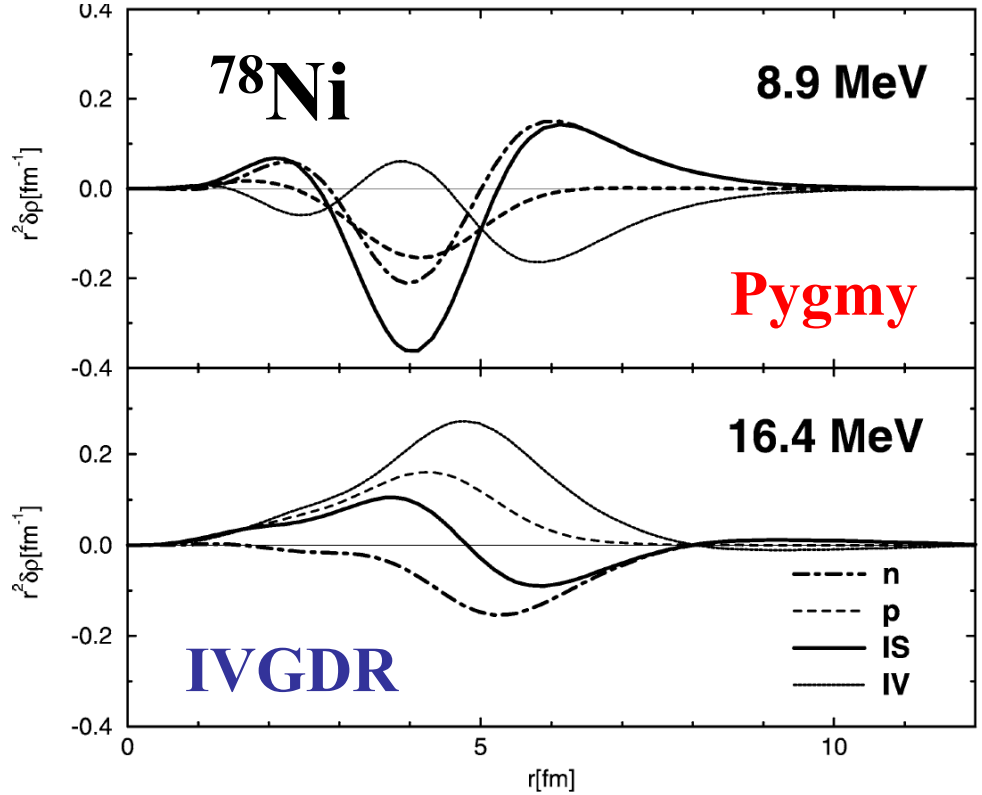
Deformed nucleus

26Ne: J. Gibelin et al.

Relativistic RPA calc.

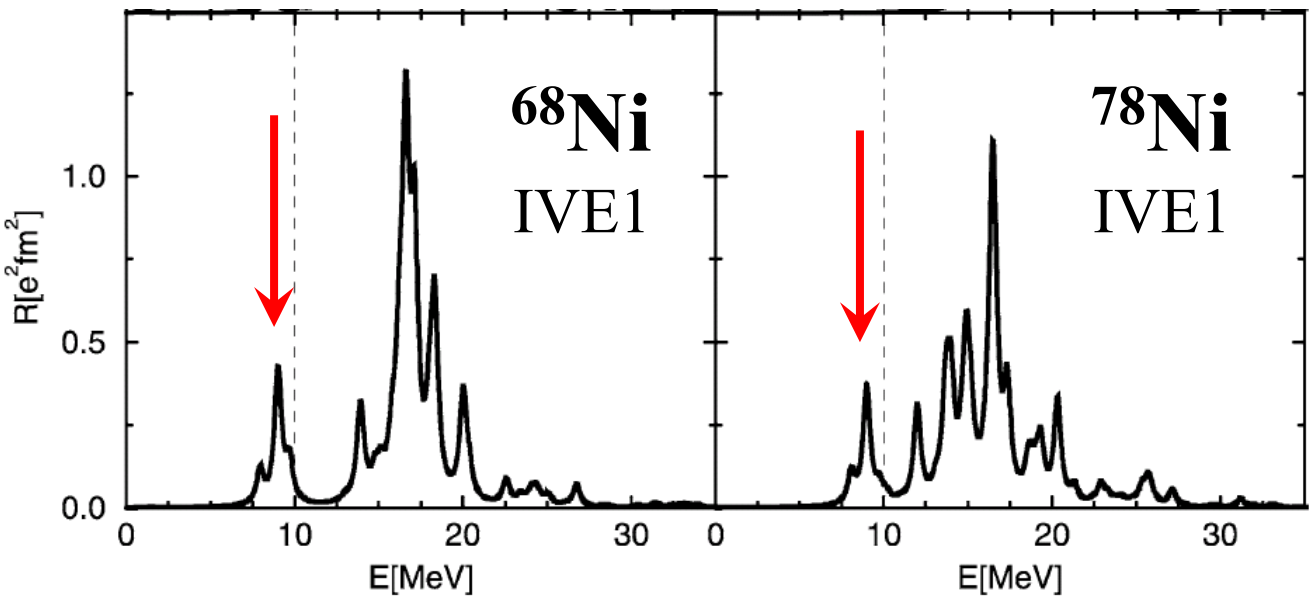
Vretenar, Paar, Ring *et al.*,
NPA692, 496.

Fully self-consistent calc.
Harmonic Oscillator basis.



9.0 MeV, 4.3 % EWSR

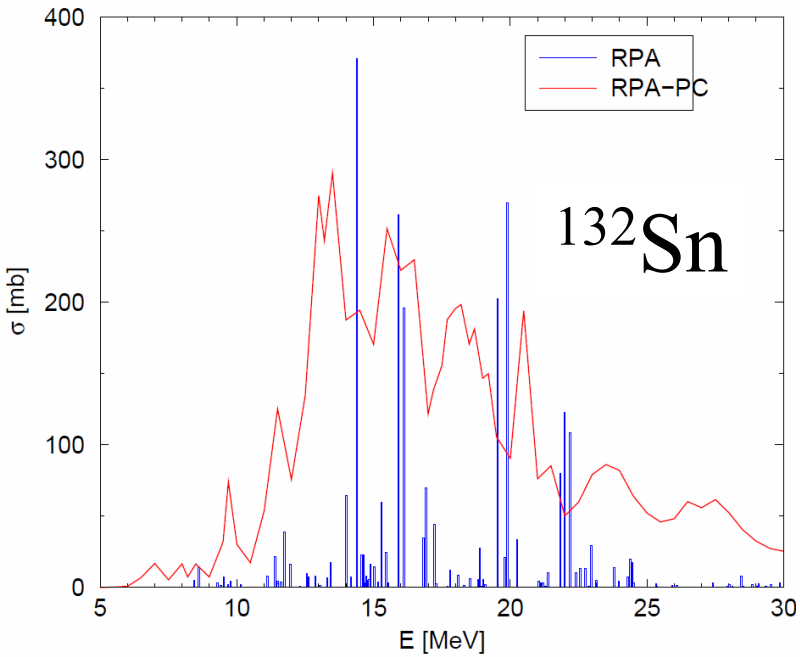
$1f_{5/2} \rightarrow 2d_{5/2}$	0.261
$2p_{3/2} \rightarrow 2d_{5/2}$	0.229
$1f_{7/2} \rightarrow 1g_{9/2}$	0.113
$2p_{1/2} \rightarrow 2d_{3/2}$	0.103
$1f_{5/2} \rightarrow 2d_{3/2}$	0.100
$2p_{3/2} \rightarrow 3s_{1/2}$	0.082
$2p_{1/2} \rightarrow 3s_{1/2}$	0.014
$1f_{5/2} \rightarrow 1g_{7/2}$	0.010
$1f_{5/2} \rightarrow 2d_{3/2}$	0.003



Skyrme-RPA (+phonon coupl.)

Bortignon, Colo, *et al.*

Skyrme HF-BCS.
Fully self-consistent calc.
Harmonic Oscillator basis.



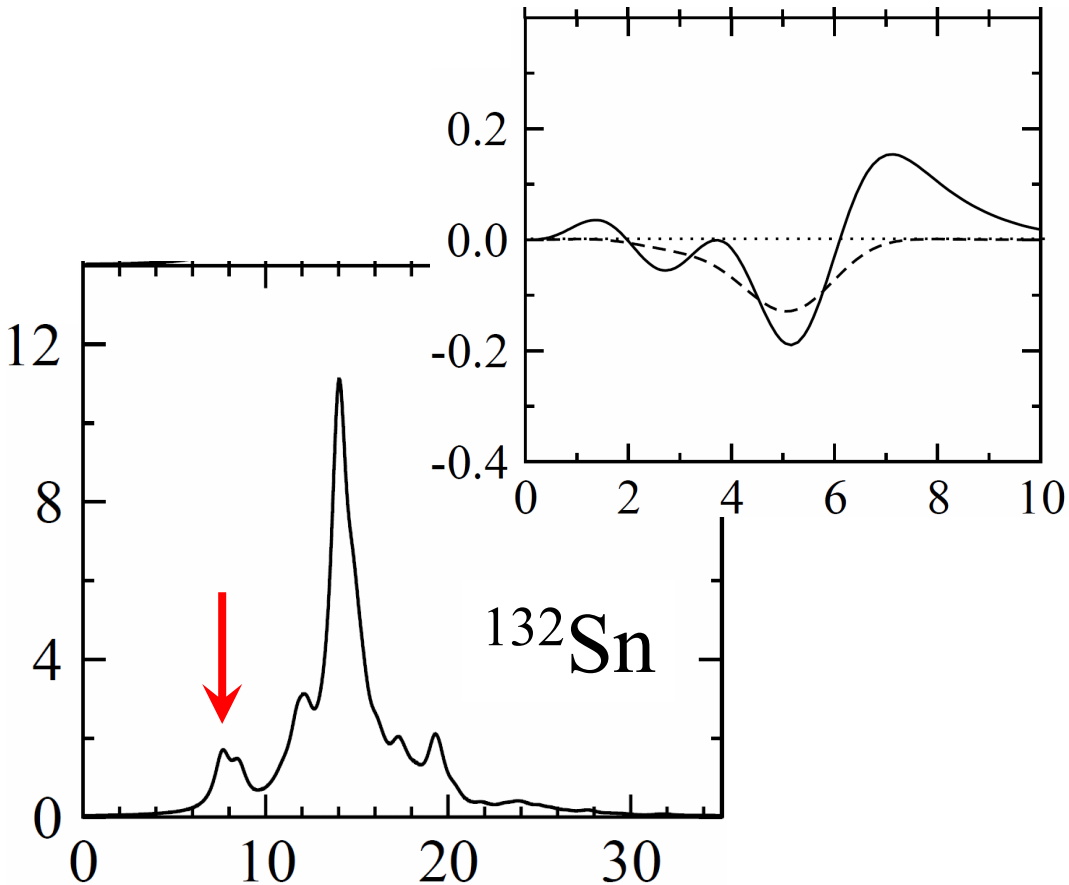
PLB 601, 27

At low energy,
no single "collective" states.

Relativistic QRPA

Vretenar, Paar, Ring *et al.*

Fully self-consistent calc.
Harmonic Oscillator basis.

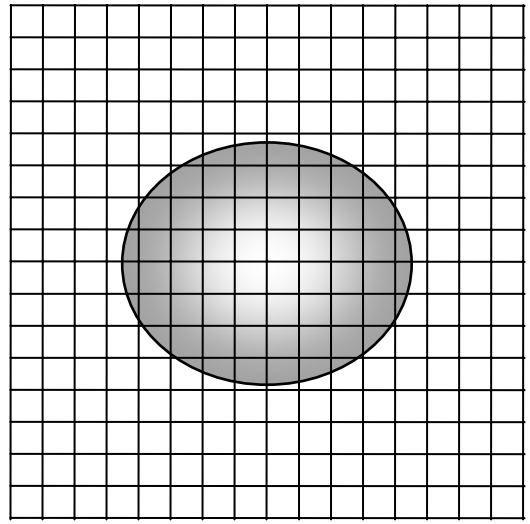


PRC 67, 034312

Motivations

- What is the nature of pygmy resonance?
- How about in deformed nuclei?

Mixed Representation RPA

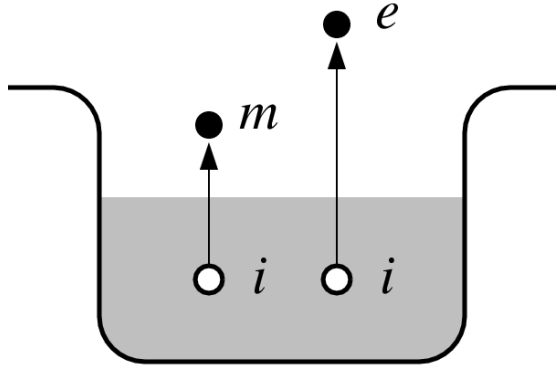


The coordinate representation for particles states, while the HF basis for holes states.

$$\psi^\dagger(x) = a^\dagger(x) + \sum_i \varphi_i^*(x)\, b_i \qquad x = \{\boldsymbol{r}, \sigma, \tau\}$$

Including of continuum states.

$$a^\dagger(x) = \sum_m \varphi_m^*(x)\, a_m^\dagger + \int_0^\infty \mathrm{d}e\, \varphi_e^*(x)\, a_e^\dagger$$



Energy cut-off

$$E_{\mathrm{cut}} = \frac{\hbar^2}{2m}\left(\frac{\pi}{a}\right)^2 \sim 500\mathrm{MeV}$$

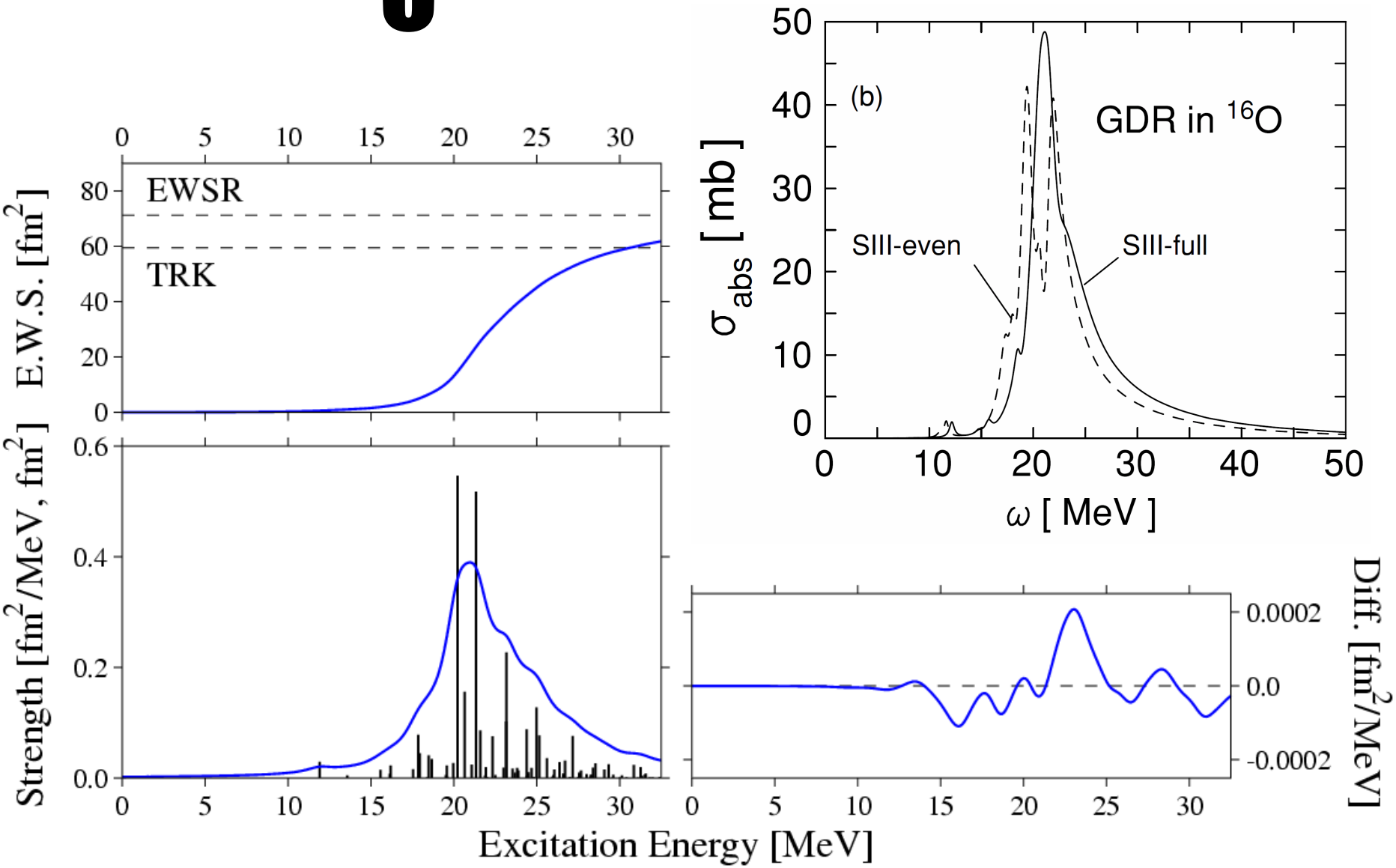
Fully Self-consistent RPA Calculation

including all terms of Skyrme force.

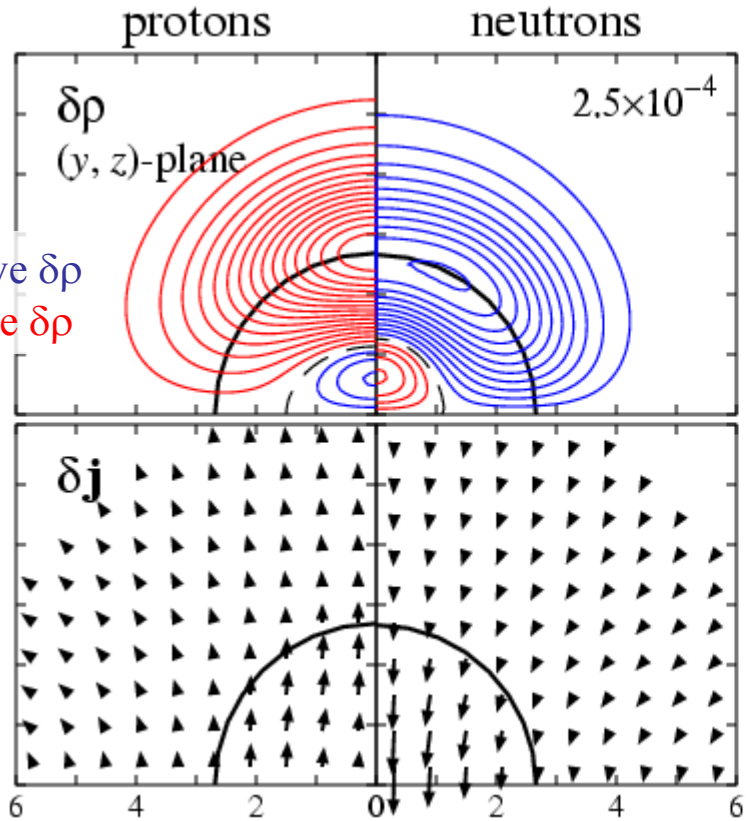
R. H. Lemmer and M. Veneroni, PR **170**, 883.
A. Muta *et al.*, PTP **108**, 1065.
H. Imagawa and Y. Hashimoto, PRC **67**, 037302.
H. Imagawa, Ph.D. thesis, 2003.
T. Inakura *et al.*, NPA 768, 61.

^{16}O

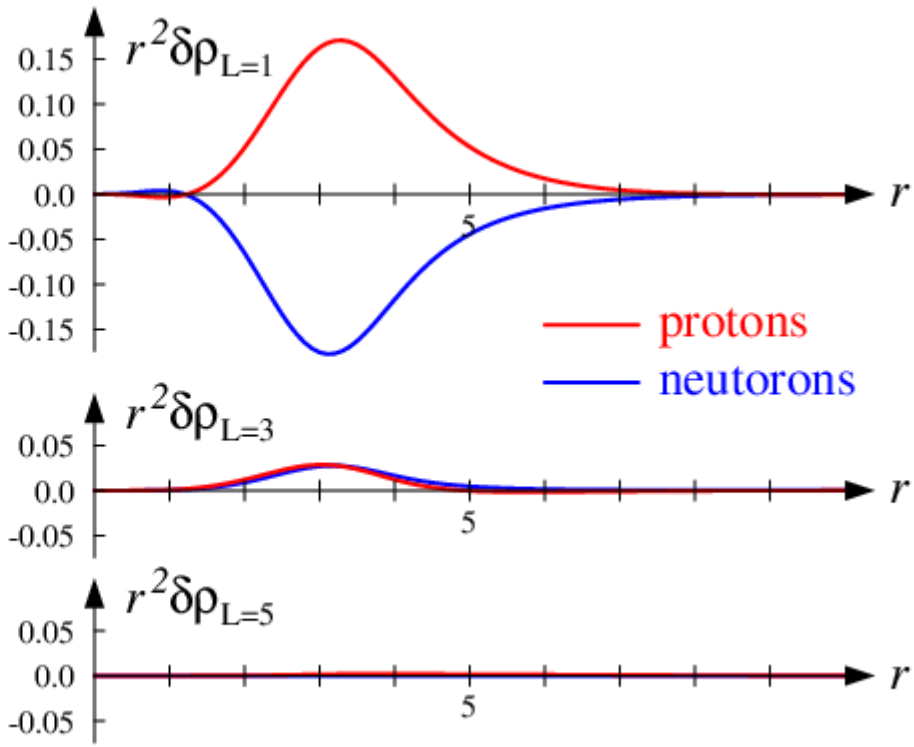
TDHF calc. by Nakatsukasa and Yabana,
Phys. Rev. C71, 024301



Transition Density in GDR

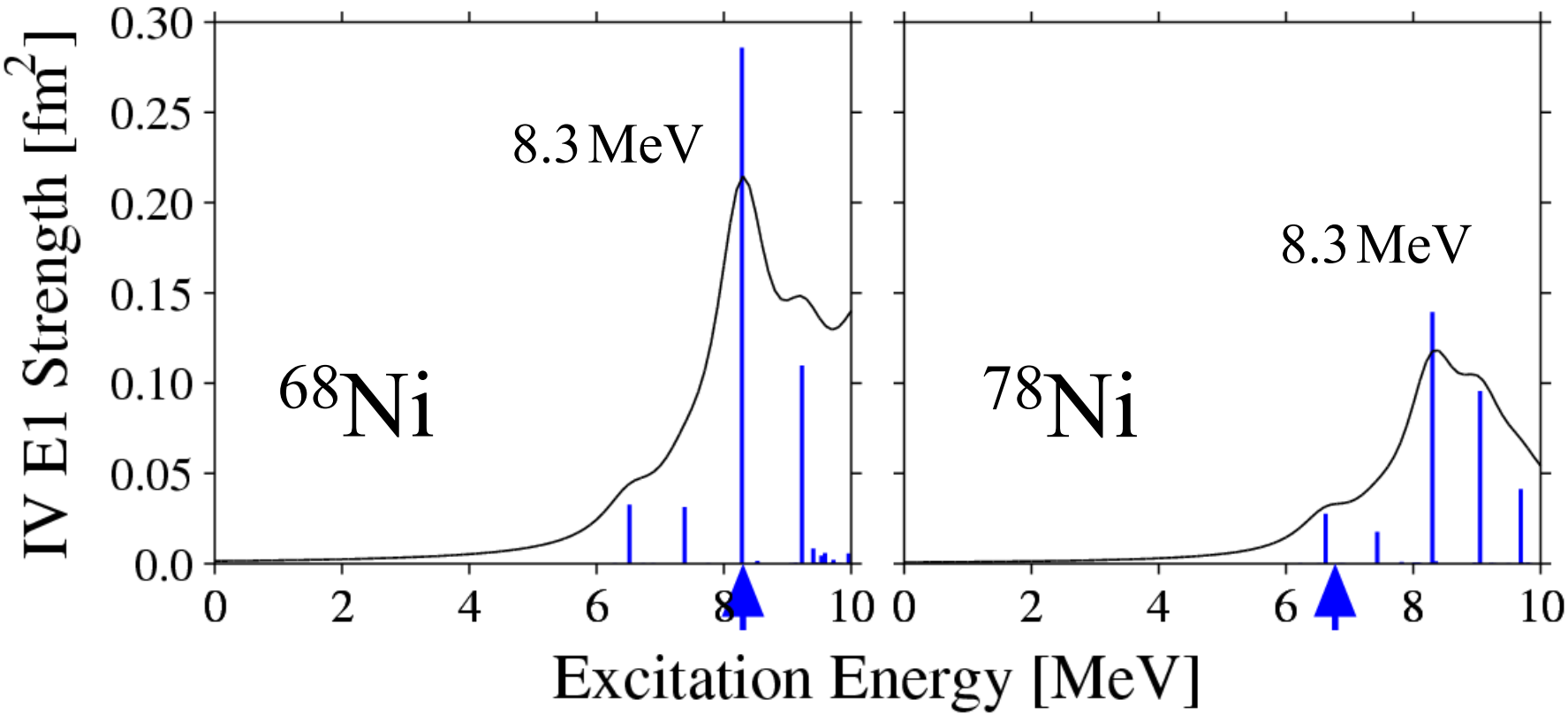


negative δρ
positive δρ



SkM*
R_{box}= 10 fm

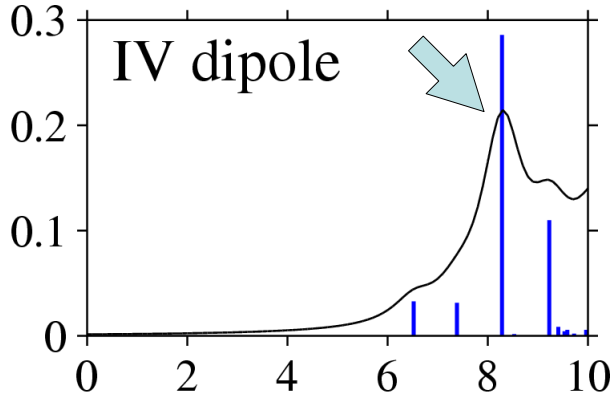
Low-lying dipole strengths in ^{68,78}Ni

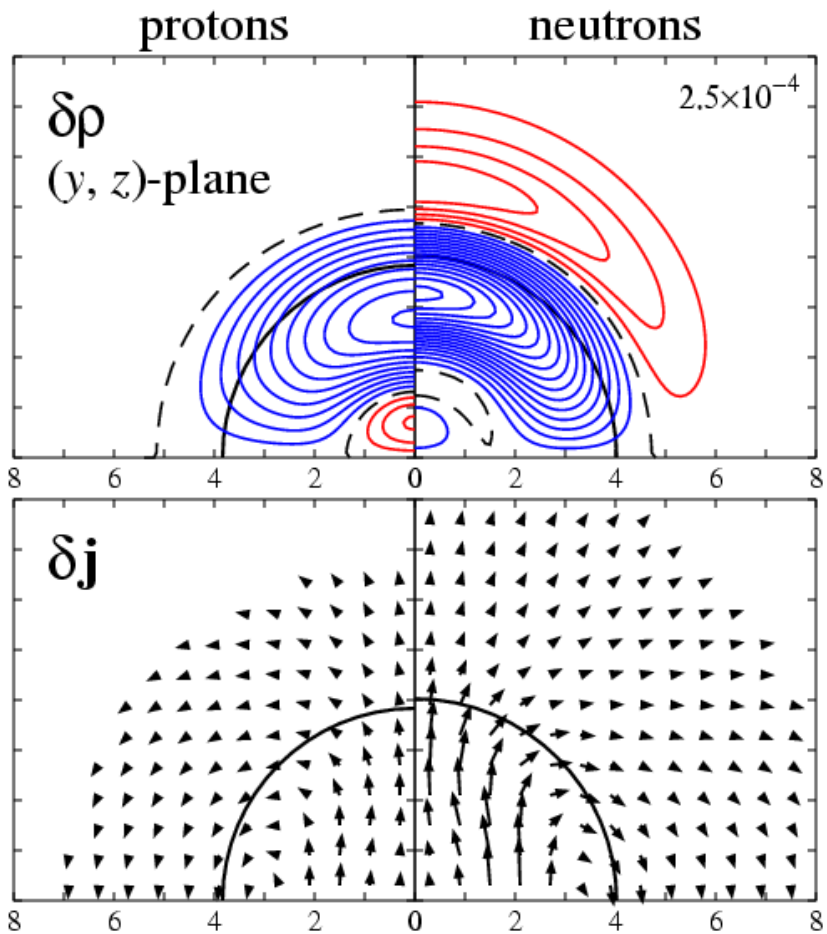


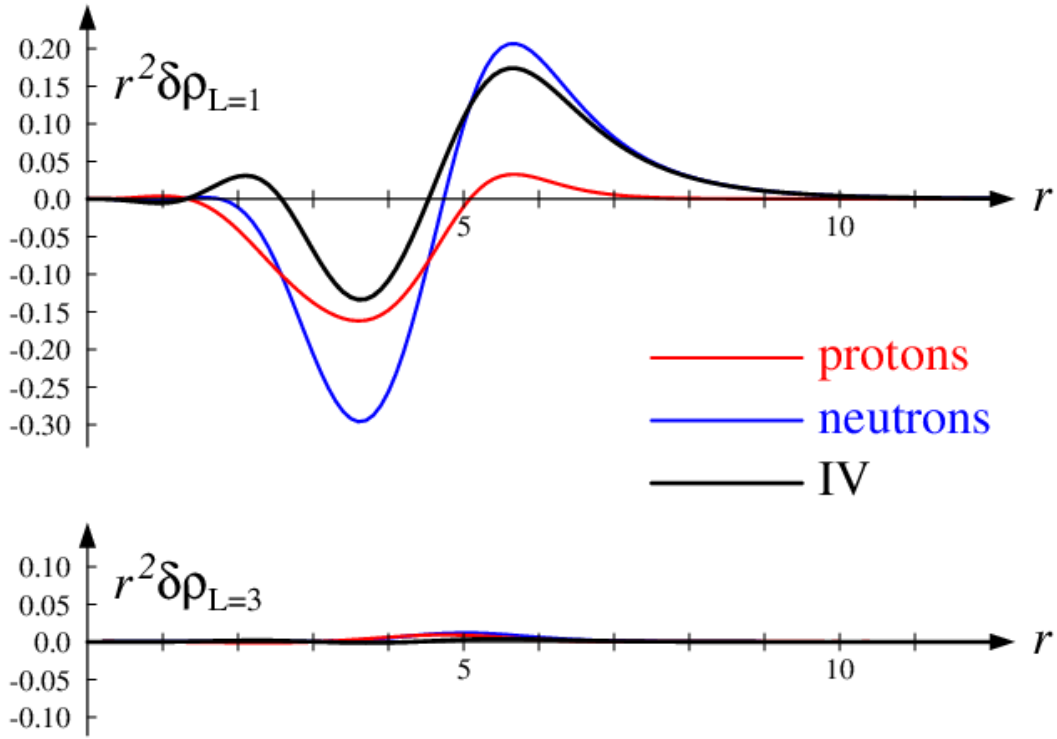
SkM*
Γ= 1.0 MeV
R_{ox}= 12 fm

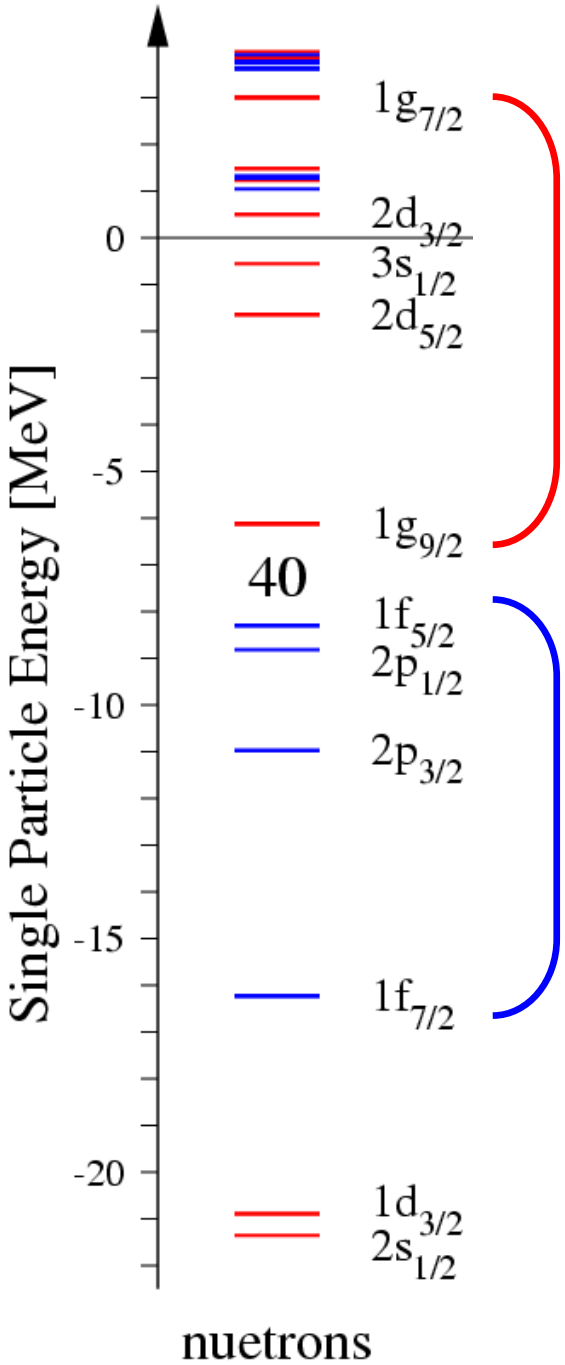
^{68}Ni

8.3 MeV
0.8 % EWSR
1.0 % TRK

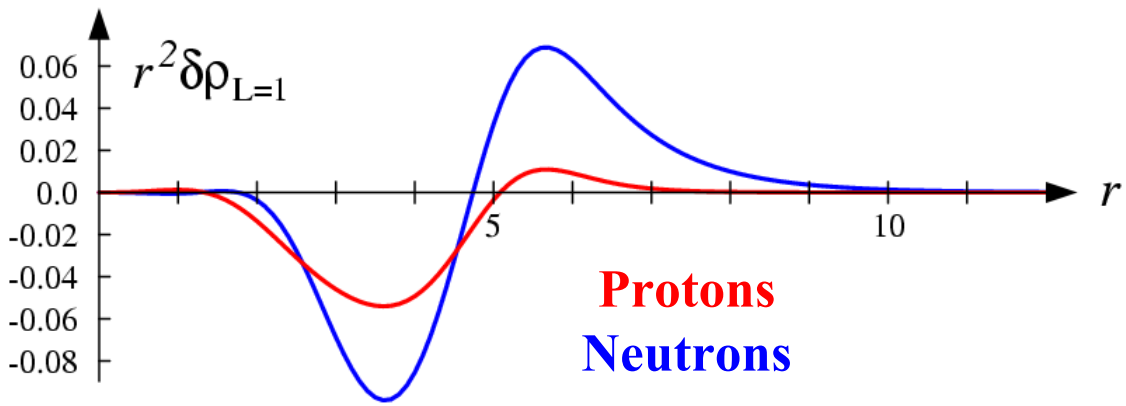




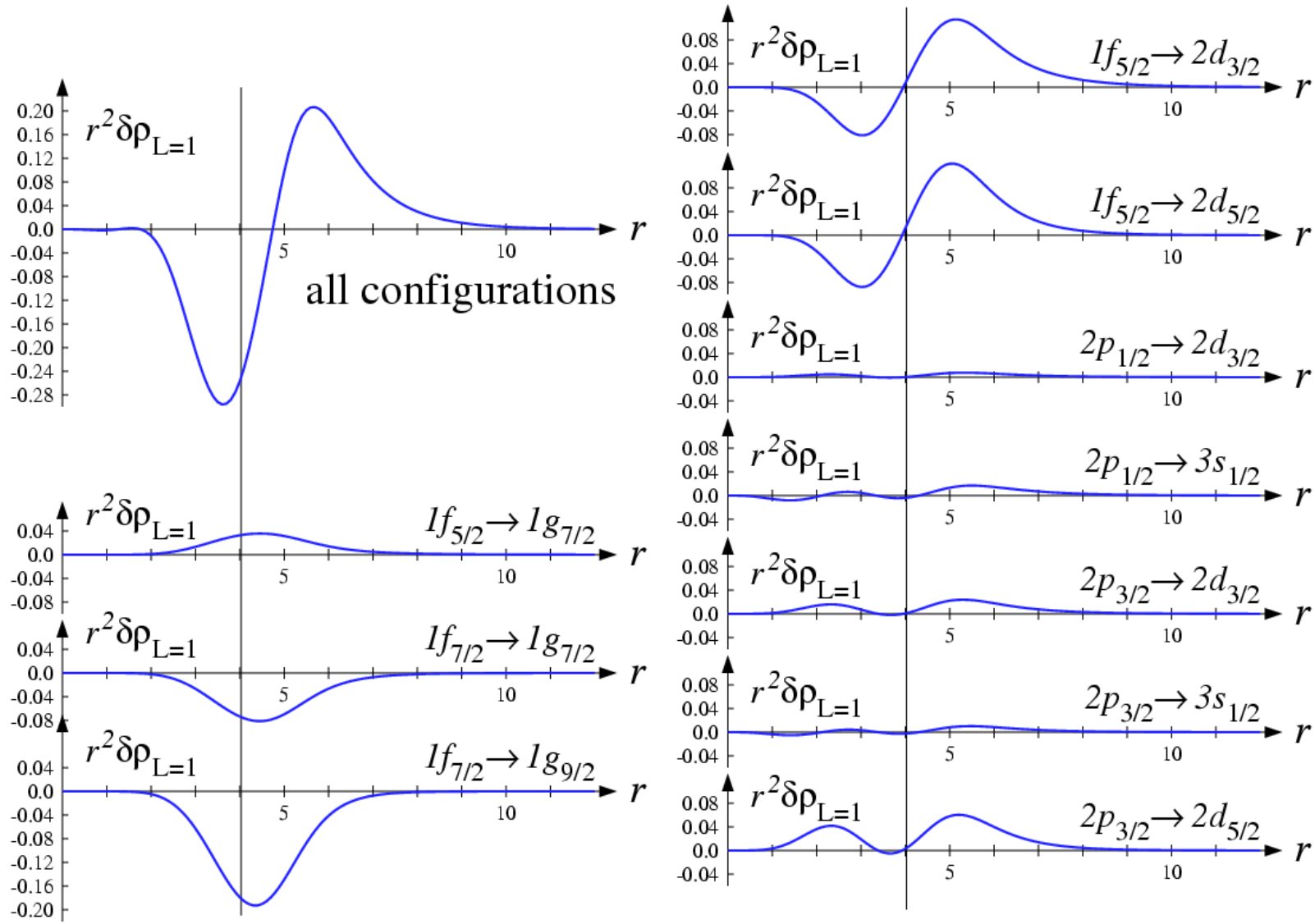




protons	0.125
neutrons	0.875
$\nu : 1f_{5/2} \rightarrow 2d_{3/2}$	0.385
$\nu : 1f_{5/2} \rightarrow 2d_{5/2}$	0.268
$\nu : 1f_{7/2} \rightarrow 1g_{9/2}$	0.073
$\nu : 1f_{7/2} \rightarrow 1g_{7/2}$	0.036
$\nu : 2p_{3/2} \rightarrow 2d_{5/2}$	0.028
$\nu : 2p_{3/2} \rightarrow 2d_{3/2}$	0.015
$\nu : 2p_{1/2} \rightarrow 3s_{1/2}$	0.010
$\nu : 2p_{3/2} \rightarrow 3s_{1/2}$	0.003
$\nu : 2p_{1/2} \rightarrow 2d_{3/2}$	0.002
$\nu :\rightarrow$ Continuum	0.053

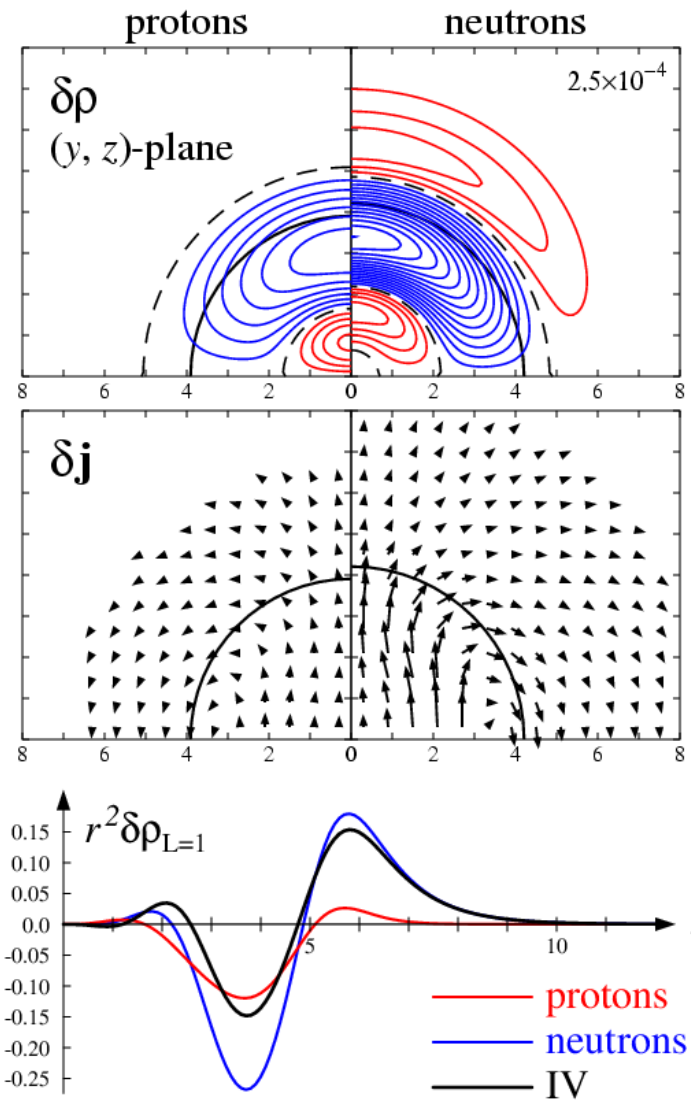


Decomposed transition densities



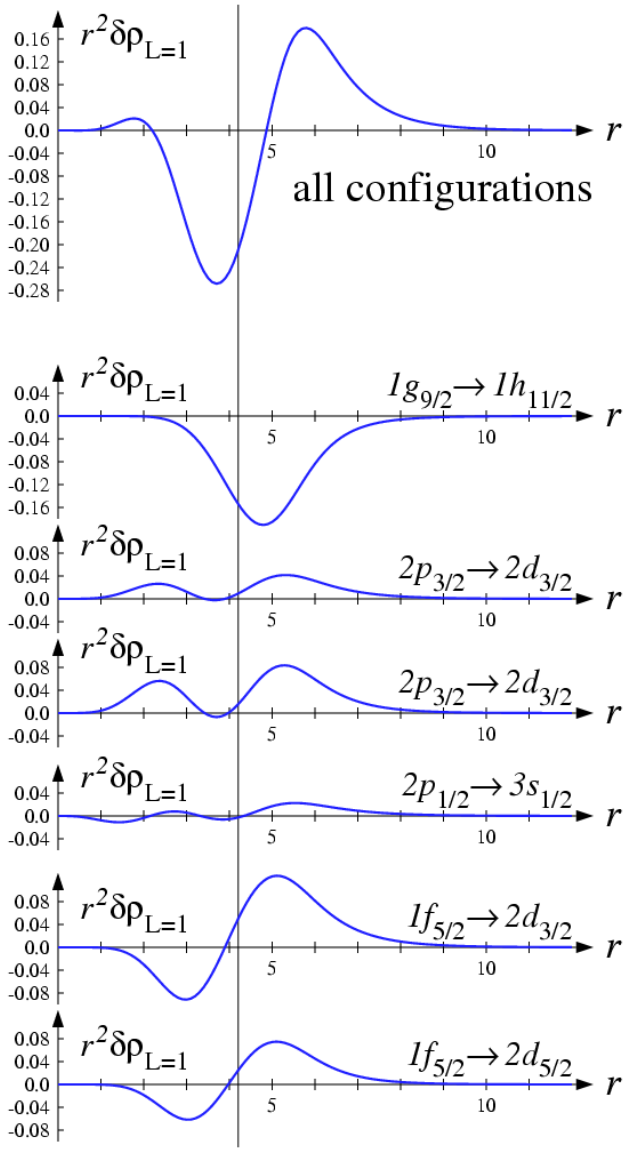
$\ell\text{max} \rightarrow \ell\text{max} + 1$

8.3MeV state in ^{78}Ni



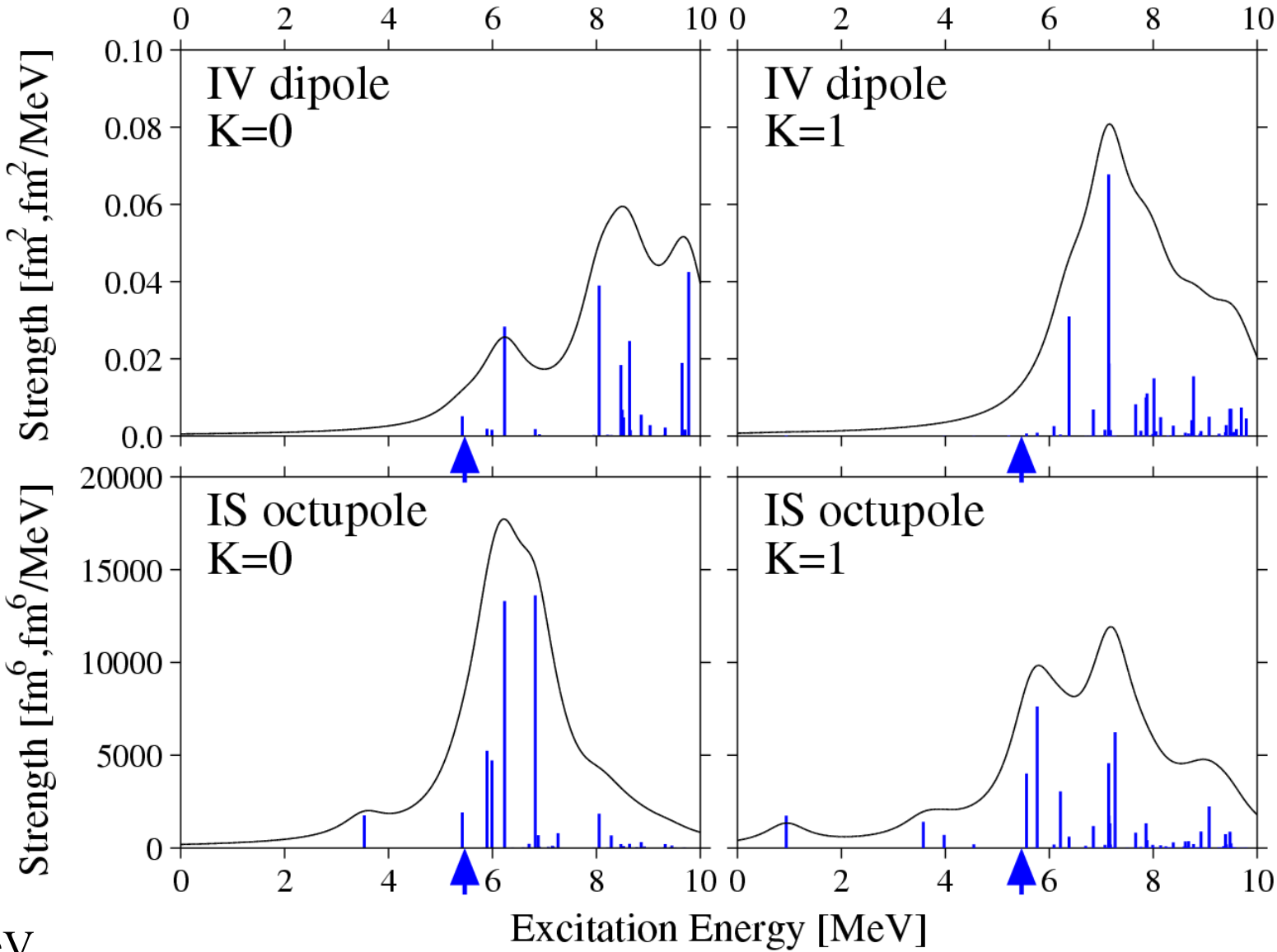
$\nu : 1f_{5/2} \rightarrow 2d_{3/2}$	0.378
$\nu : 1f_{5/2} \rightarrow 2d_{5/2}$	0.268
$\nu : 1g_{9/2} \rightarrow 1h_{11/2}$	0.085
$\nu : 2p_{3/2} \rightarrow 2d_{5/2}$	0.070
$\nu : 2p_{3/2} \rightarrow 2d_{3/2}$	0.045
$\nu : 2p_{1/2} \rightarrow 3s_{1/2}$	0.018
$\pi : 1d_{7/2} \rightarrow 1g_{9/2}$	0.017
$\pi : 1d_{3/2} \rightarrow 2p_{9/2}$	0.012
$\pi : 1f_{7/2} \rightarrow 1g_{7/2}$	0.011
$\pi : 2s_{1/2} \rightarrow 2p_{3/2}$	0.005
$\pi : 2s_{1/2} \rightarrow 2p_{1/2}$	0.005
$\pi : 1d_{3/2} \rightarrow 2p_{1/2}$	0.005
$\rightarrow$ Continuum	0.068

Cf.
ν-threshold energy: 6.8MeV



^{72}Fe

$\beta_2 = 0.18$



SkM*

$\Gamma = 1.0$ MeV

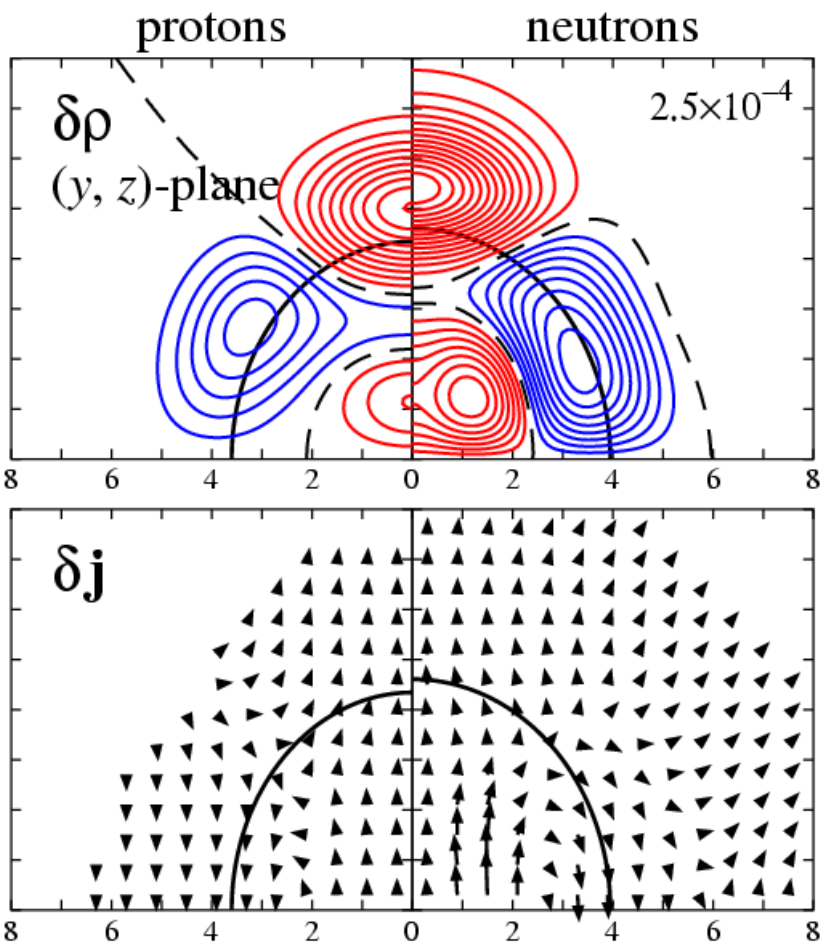
$R_{box} = 12$ fm

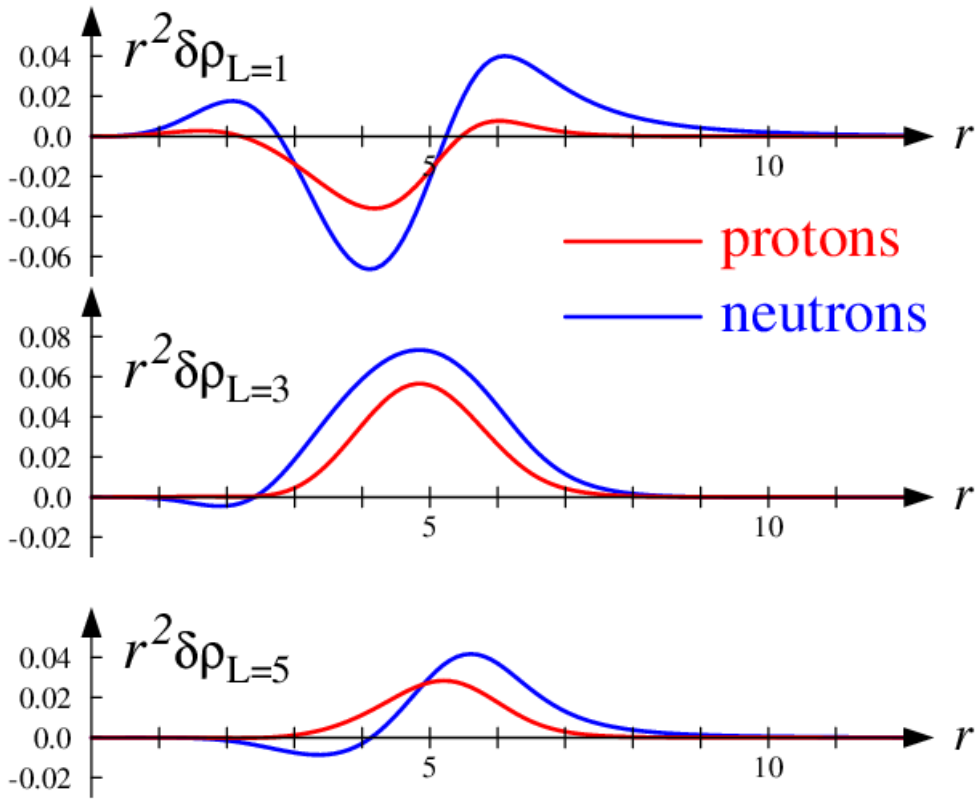
8.1 MeV K=0 state in ^{72}Fe

0.4 % TRK

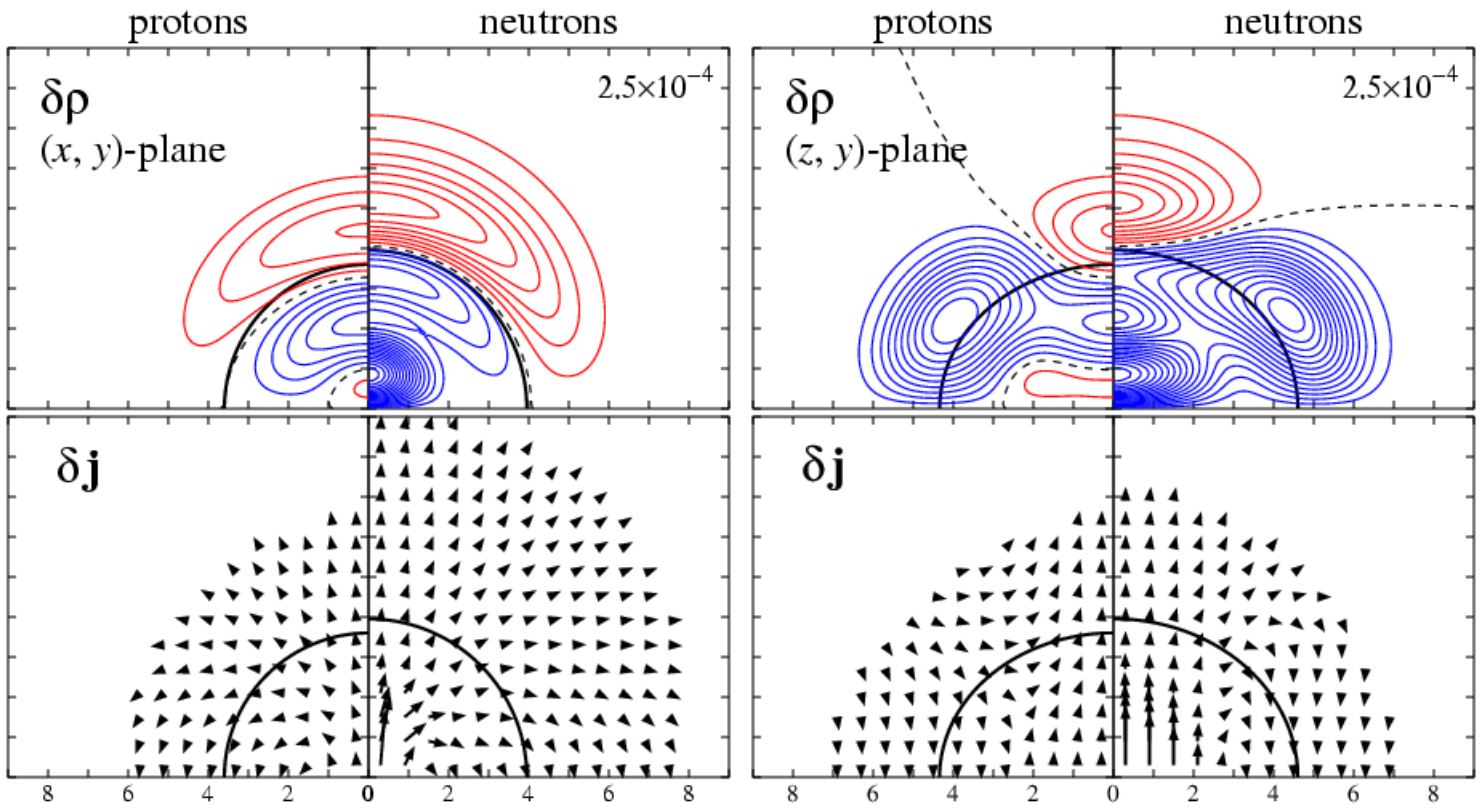
$\nu : [301]3/2 \rightarrow [411]3/2$	0.363
$\nu : [303]7/2 \rightarrow [413]7/2$	0.275
$\nu : [301]1/2 \rightarrow [400]1/2$	0.034
$\nu : [301]3/2 \rightarrow [422]3/2$	0.028
$\nu : [422]5/2 \rightarrow [532]5/2$	0.019
$\nu : [301]1/2 \rightarrow [411]1/2$	0.016
$\nu : [303]5/2 \rightarrow [413]5/2$	0.011

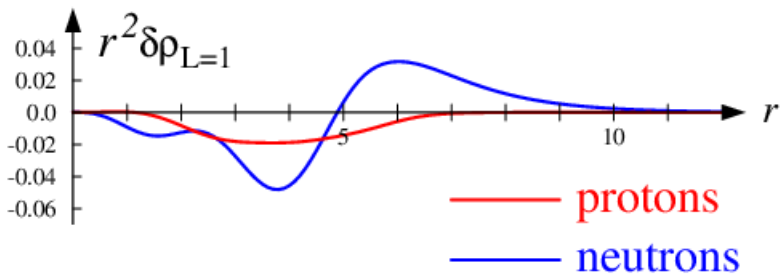
Excitations to Continuum : 0.152

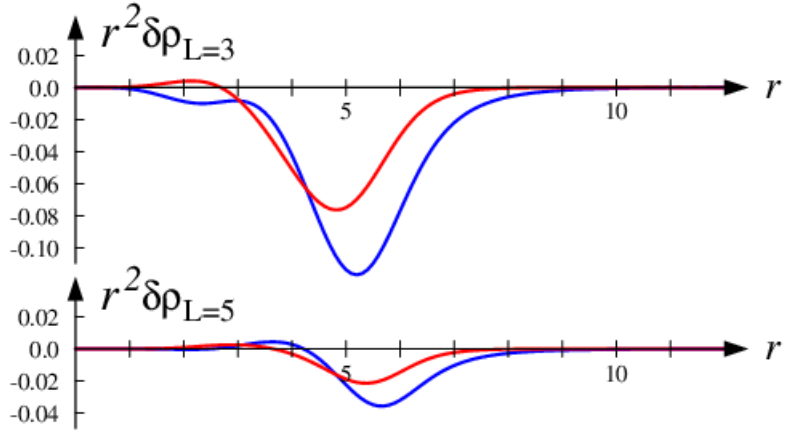




7.1 MeV K=1 state in ^{72}Fe







Summary

- Fully self-consistent Skyrme-RPA calculations in 3D mesh.

- Low-lying E1 states are obtained.
  - Superposition of some neutron excitations to loosely bound and resonant states.
  - “Moderately” collective states.
  - Small contributions of continuum states.
  - Coherence of transition densities.

- The deformation hinders the collectivity.