Shell closure evolution for exotic nuclei, Succes of the Gogny force

S. Péru

and,…many other people

Service de Physique Nucléaire, Bruyères-le-Châtel, France

sophie.peru-desenfants@cea.fr

What is a shell closure ?

What is a magic number ?

Whithin the mean field description

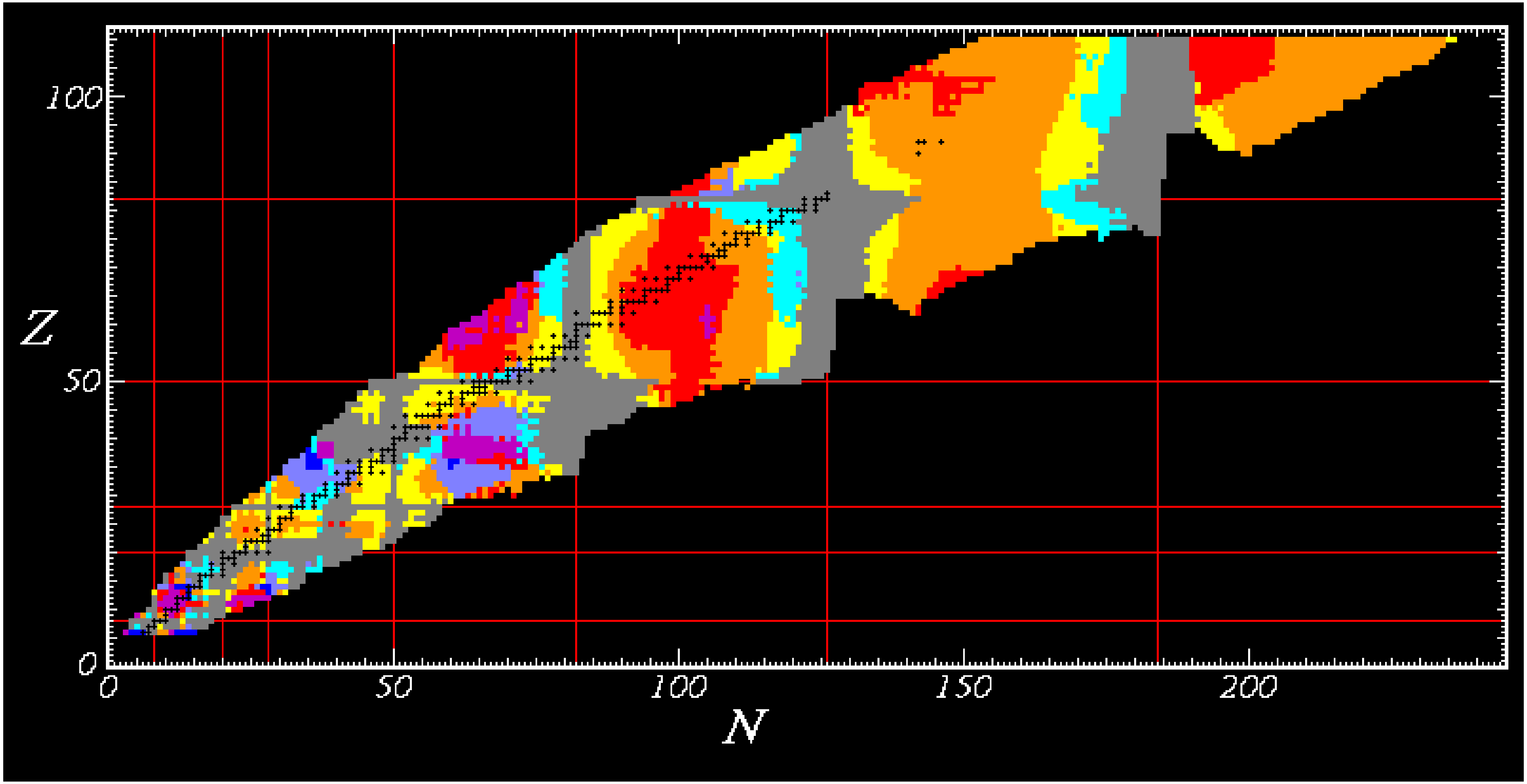
A shell closure occurs when at the ground state deformation
there is large gap in energy between the last occupied single particle level
and the first empty one.

This gap is large enougth to cancel pairing correlations.

A number of proton or neutron is magic when
there is a shell closure for spherical shape

Magic numbers and shell closures can change going far from the valley of stability.

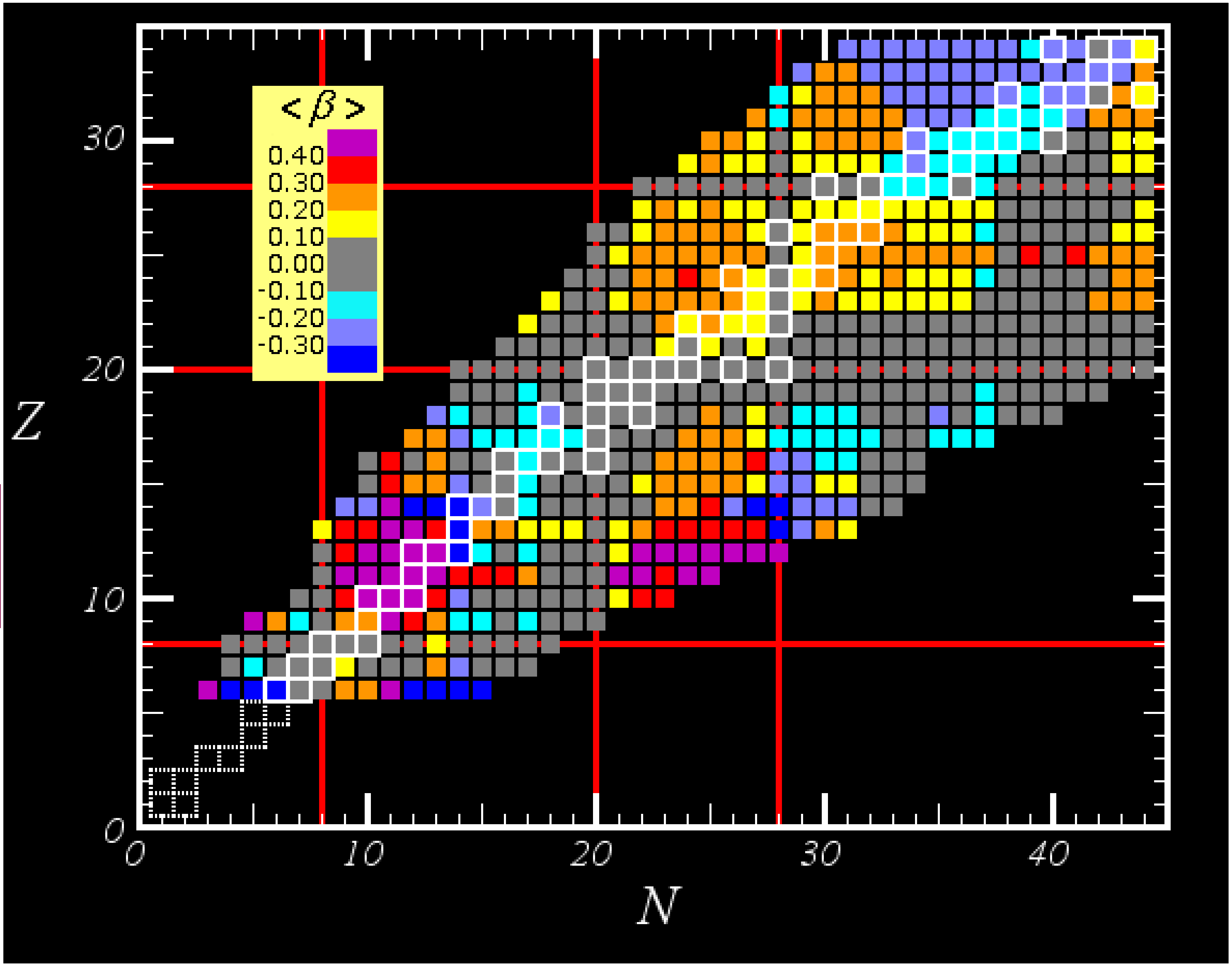
HFB+D1S



spherical prolate oblate

N=16
New magic number

A.Obertelli, S. Péru,
J.-P. Delaroche, A. Gillibert,
M. Girod et H. Goutte,
Phys. Rev. C **71**, 024304 (2005)



N=20 ,
Going begond mean field,
^{32}Mg is deformed

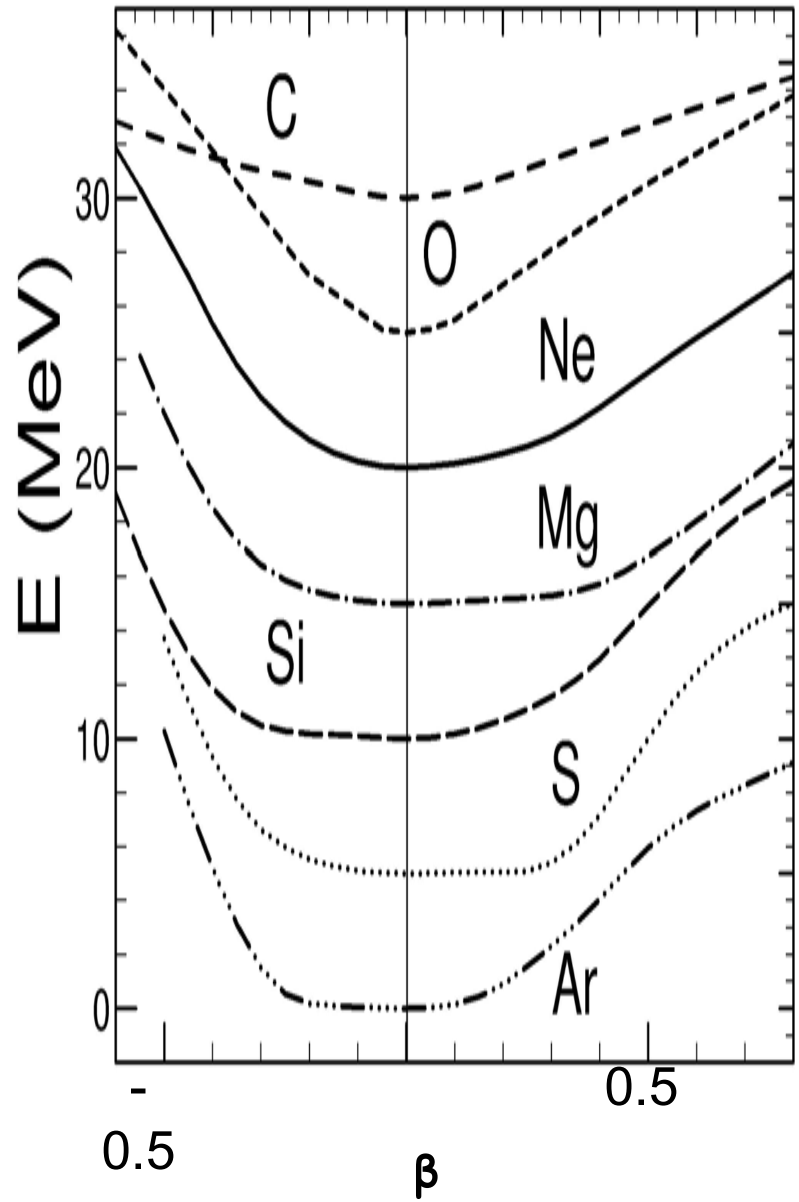
N=28
Deformed shell closure
For ^{42}Si

S. Péru, M. Girod
et J.-F. Berger,
Eur. Phys. Jour. A **9**, 35 (2000)

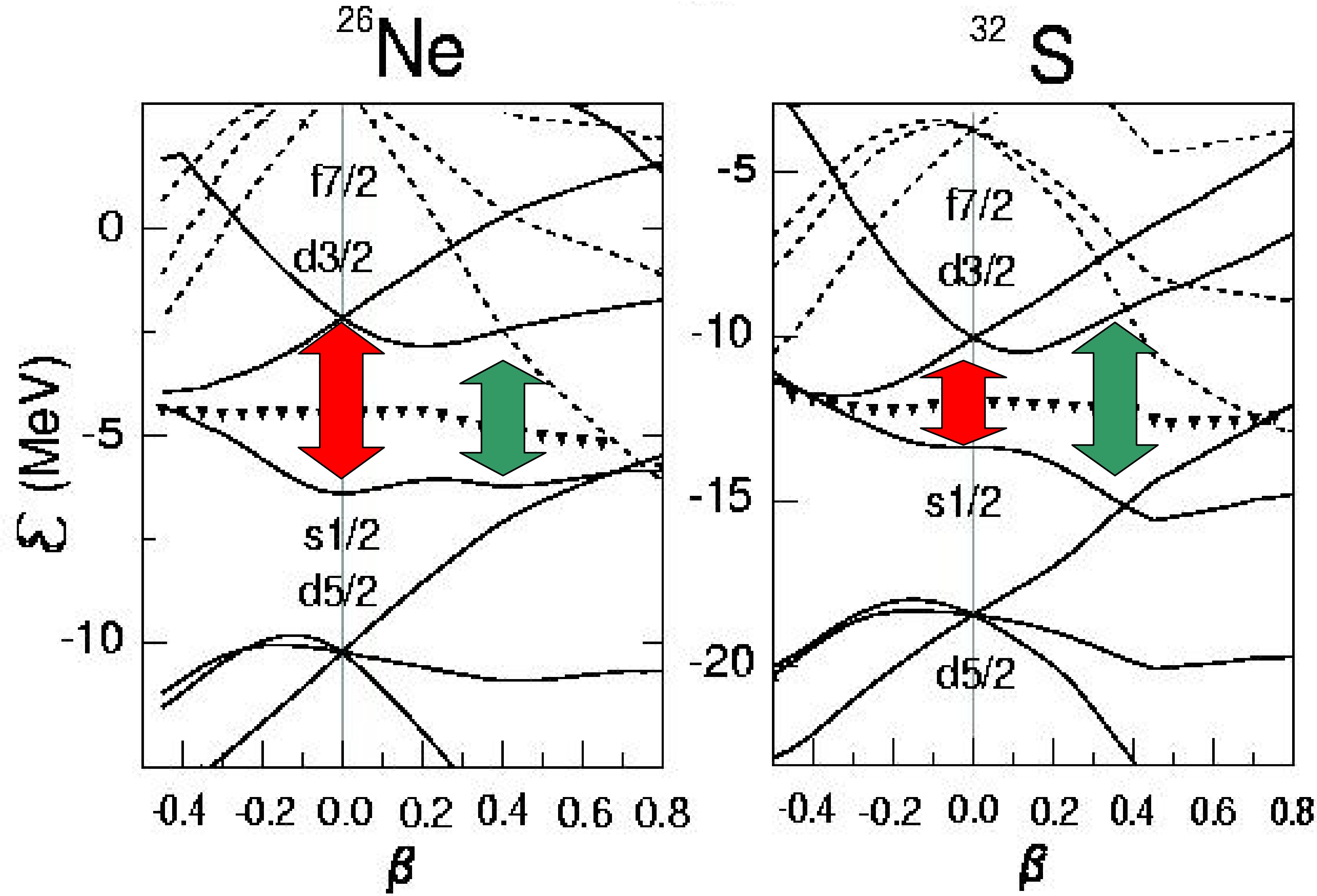
Whithin the mean field description

N=16

All N=16 isotones are predicted to be spherical at the mean field level



N=16

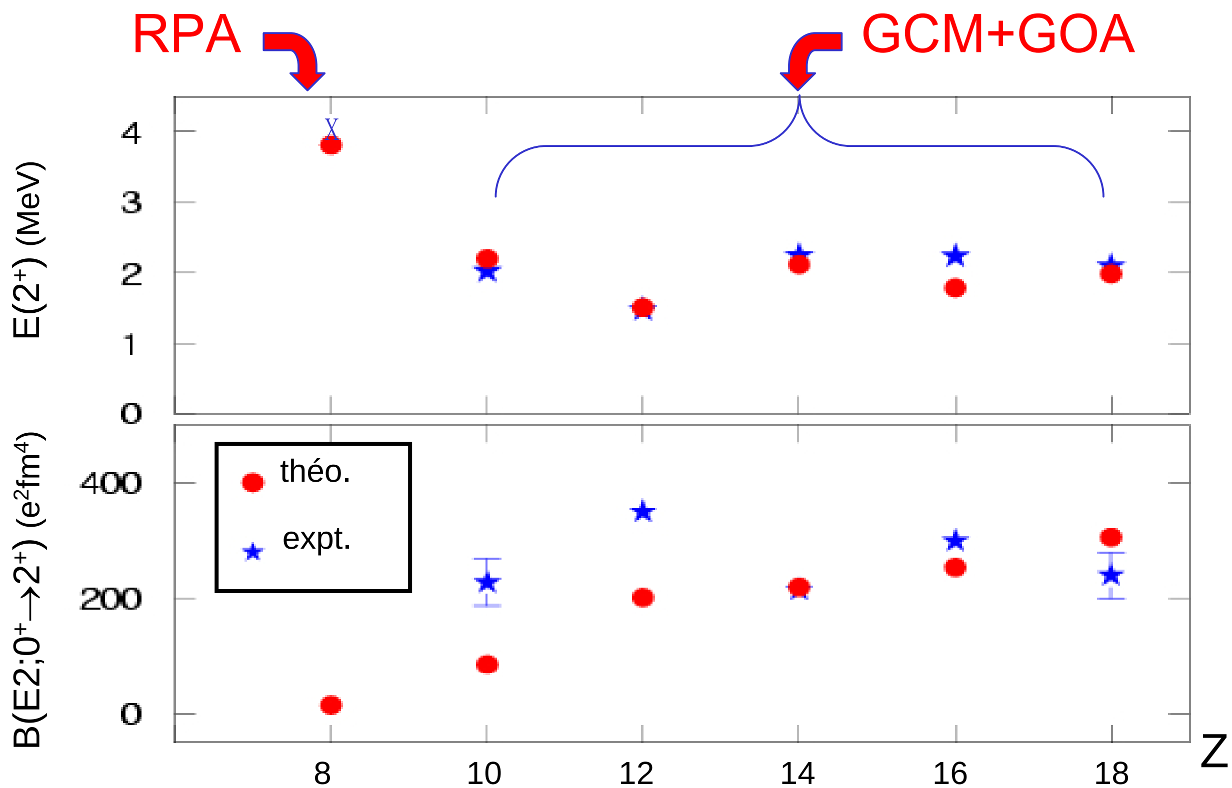


Exotic nuclei
magic number

stable nuclei
deformed shell effect

Going beyond the mean field

N=16



A. Obertelli, S. Péru, J.-P. Delaroche, A. Gillibert, M. Girod et H. Goutte, Phys. Rev. C **71**, 024304 (2005)

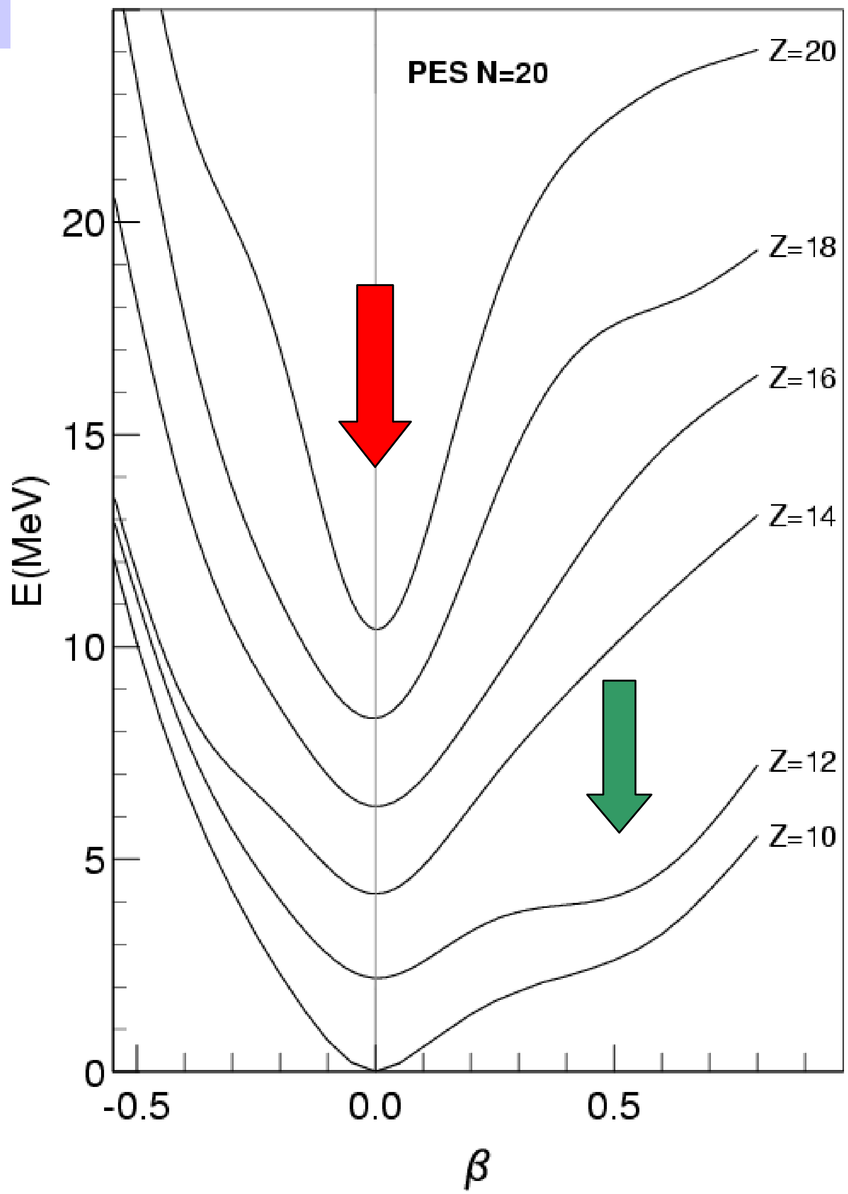
X M. Thoenessen, FINUSTAR 2005

Whithin the mean field description

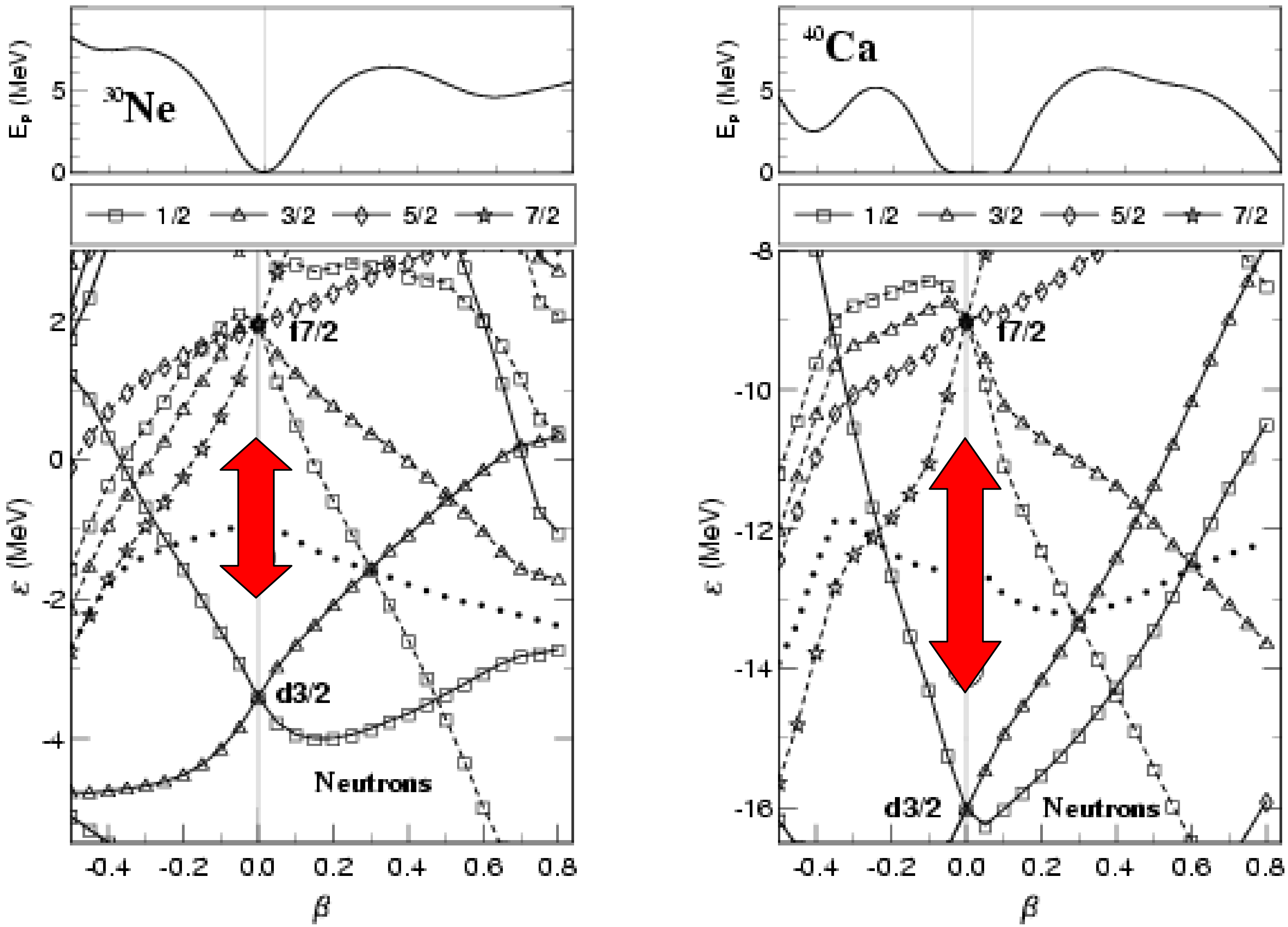
N=20

All PESs
 have a spherical minimum

For ^{32}Mg
 there is a shallow
secondary minimum



N=20



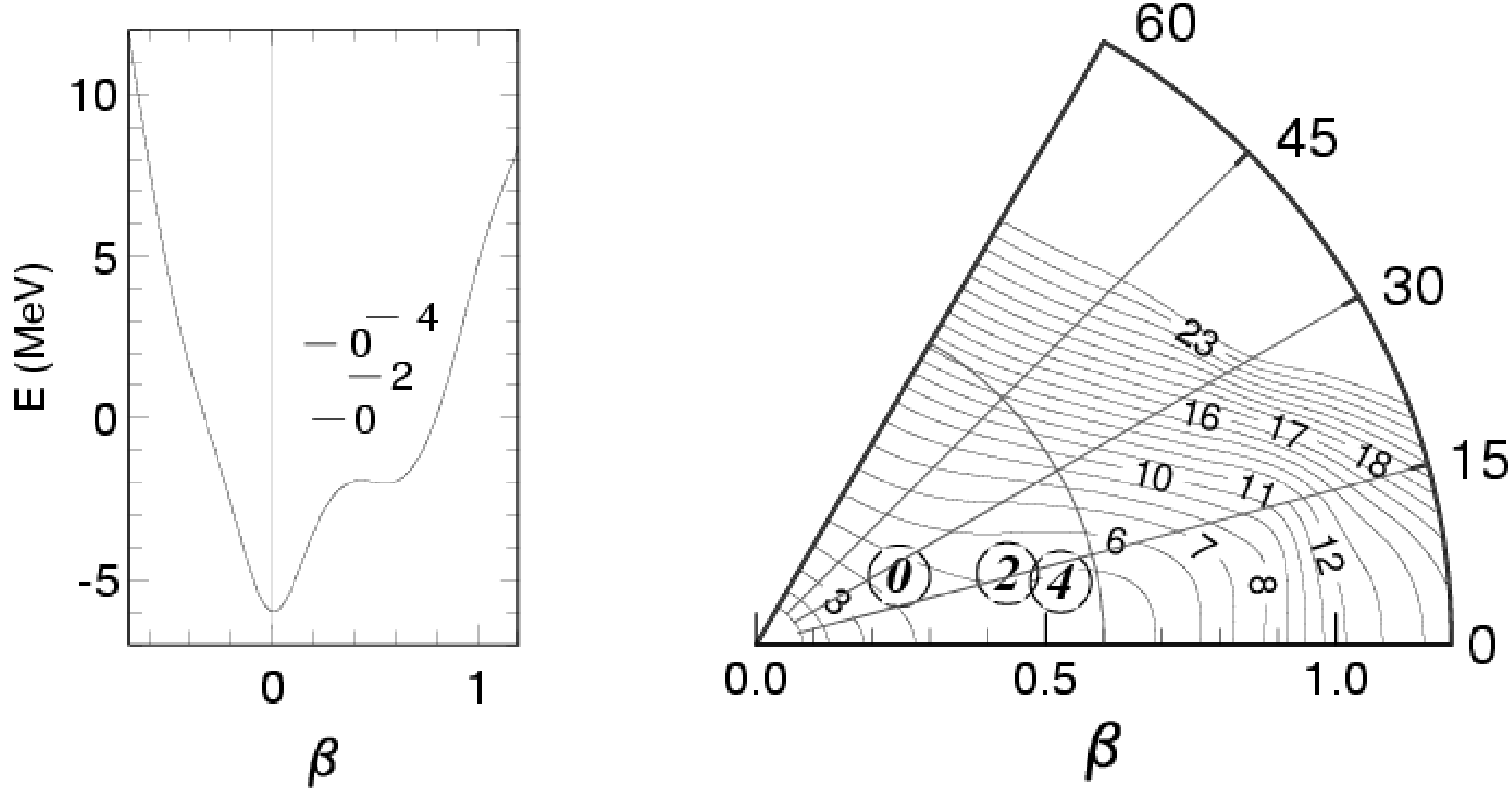
Spherical single particle gap go from 7 MeV to 5 MeV
but is large enough to cancell paring correlations.

Going beyond the mean field

N=20, ^{32}Mg

Theo. E (2^+_1) = 1.32 MeV

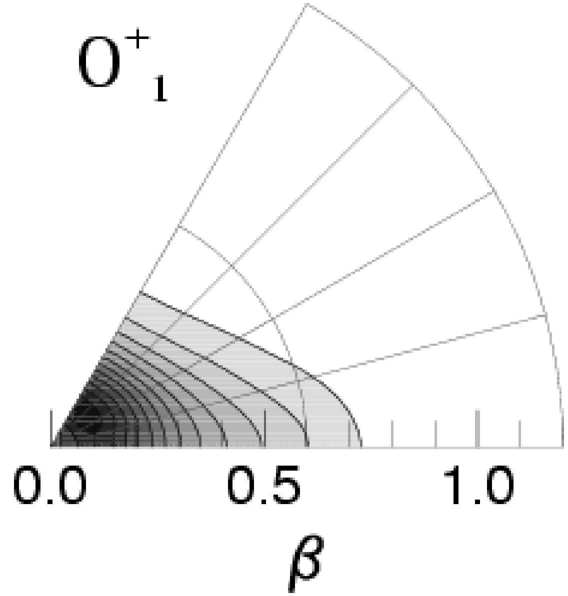
Exp. E (2^+_1) = 885 keV

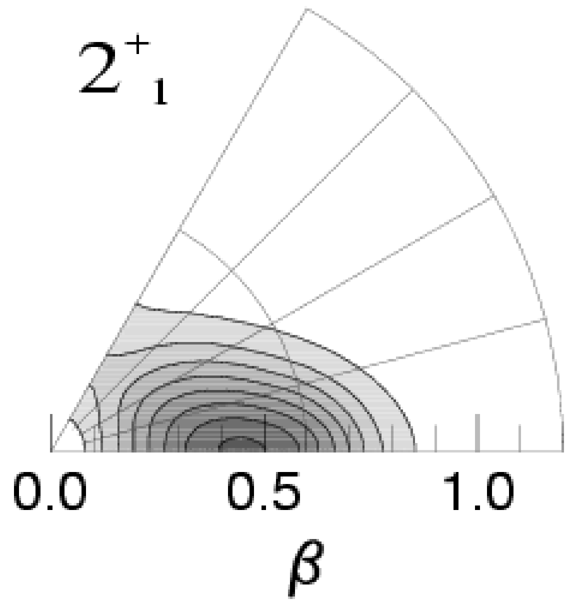


N=20, ^{32}Mg

The ground state is dynamicaly deformed

The first 2^+ state is well deformed



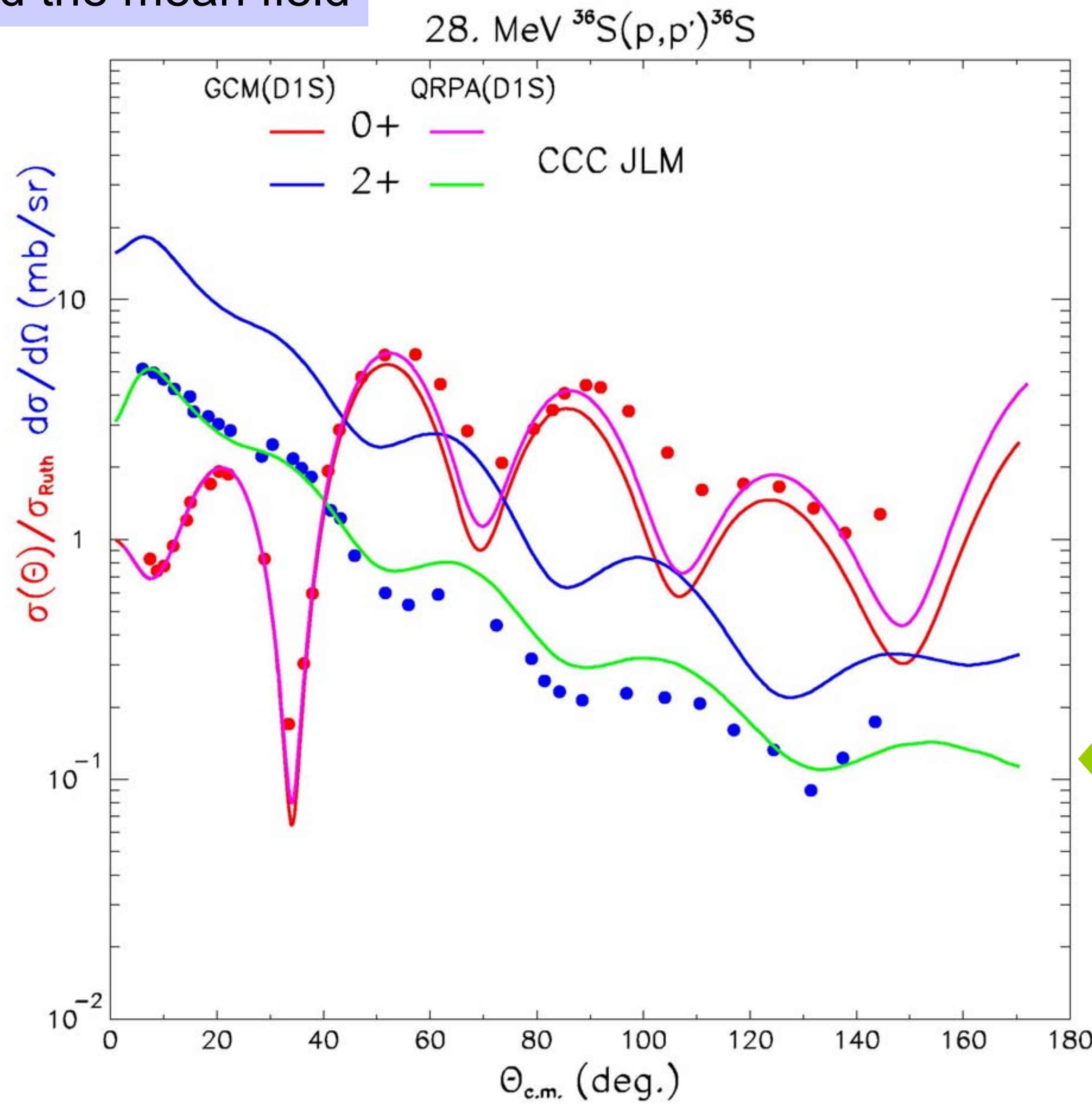


With “good” moment of inertia
Theo. E $(2^+{}_1)$ = 1.00 MeV

Exp. E $(2^+{}_1)$ = 885 keV

Going beyond the mean field

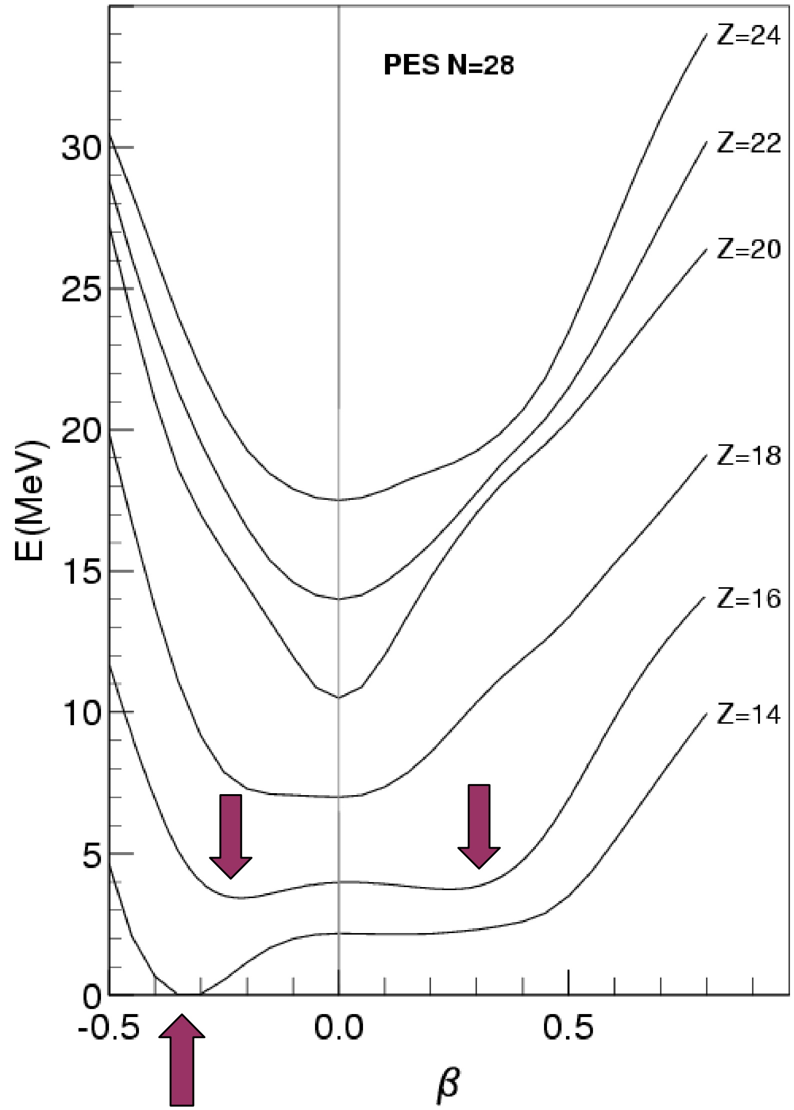
N=20, ^{36}S



QRPA

Whithin the mean field description

N=28

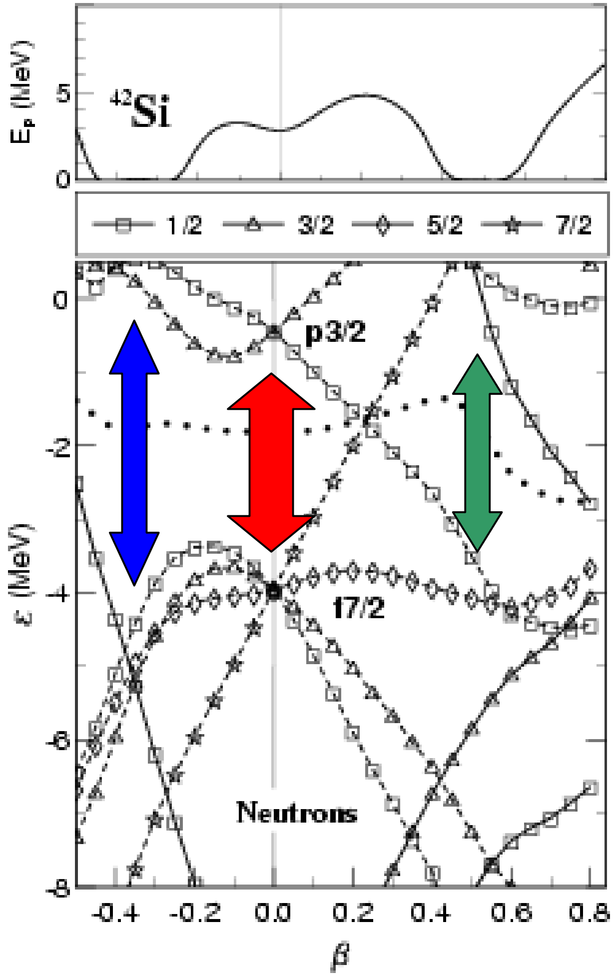


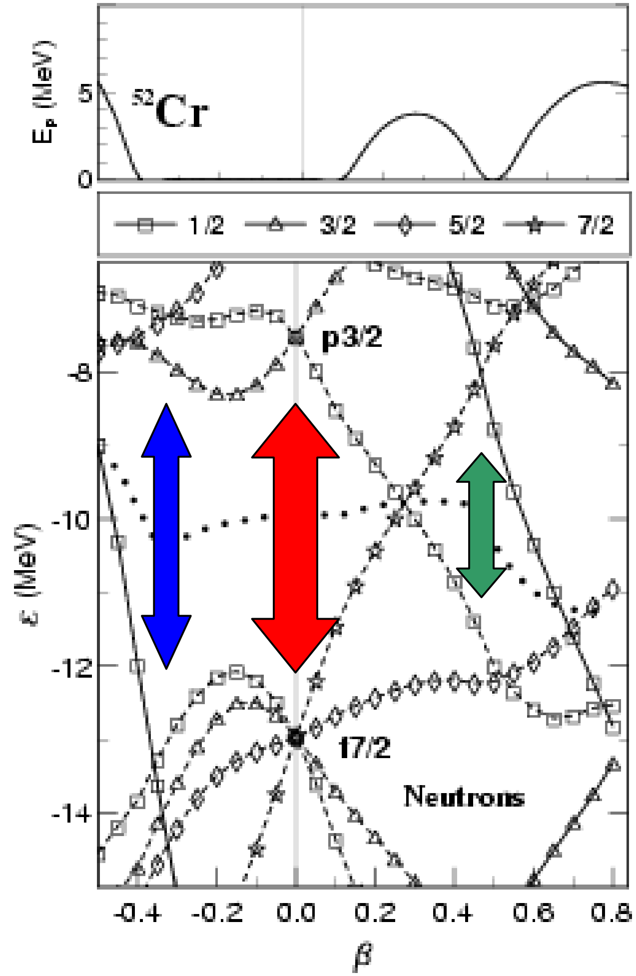
^{44}S and ^{42}Si PESs
have deformed minima

N=28 is not a magic number for exotic nuclei

For spherical shape, there is neutron pairing energy for exotic nuclei

N=28

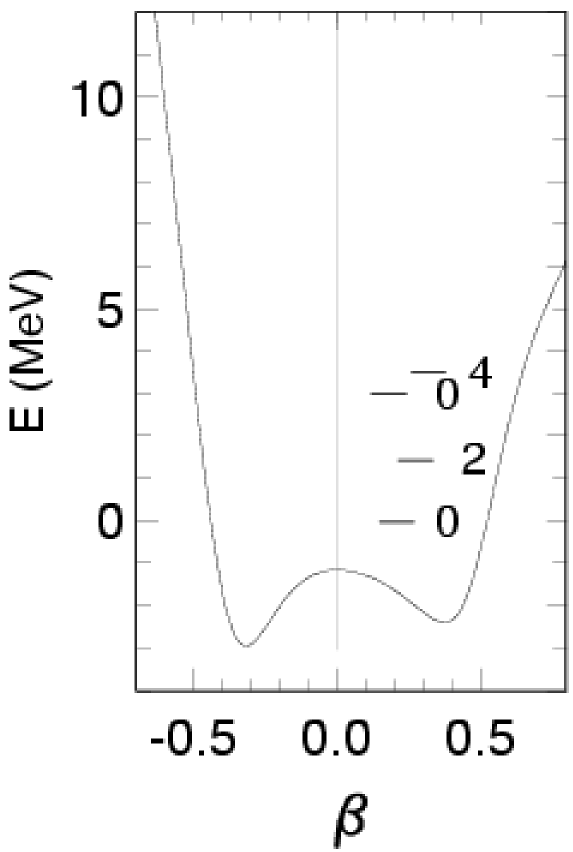


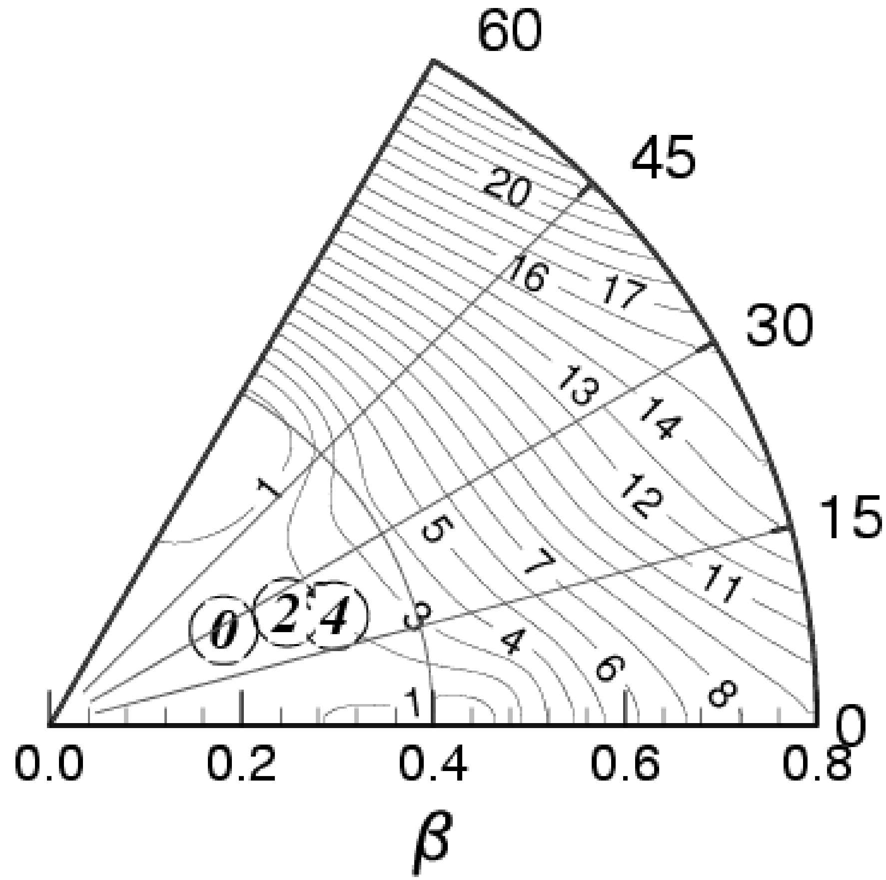


Spherical single-particle gaps go from 6 MeV for stable nuclei to 3.5 MeV for exotic ones.

Going beyond the mean field

N=28, ^{44}S





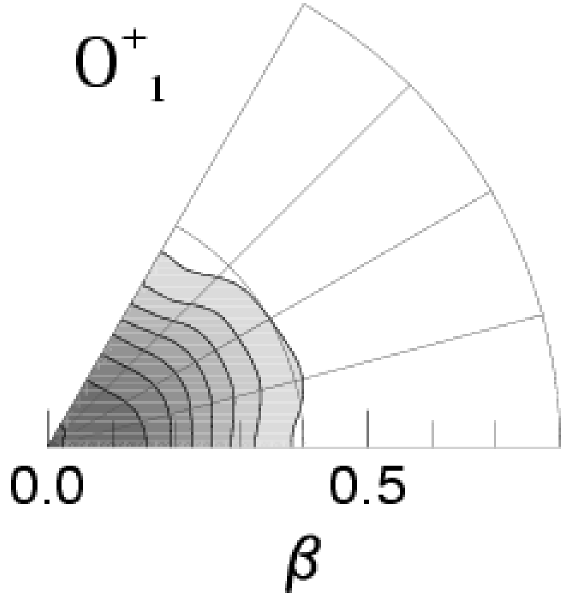
Theo. $E(2^+_1)$ = 1.46 MeV,
$B(E2, 0^+_{gs} \rightarrow 2^+_1)$ = 420 e^2fm^4

Exp. $E(2^+_1)$ = 1.297 (0.018)MeV,
$B(E2, 0^+_{gs} \rightarrow 2^+_1)$ = 314 (88) e^2fm^4

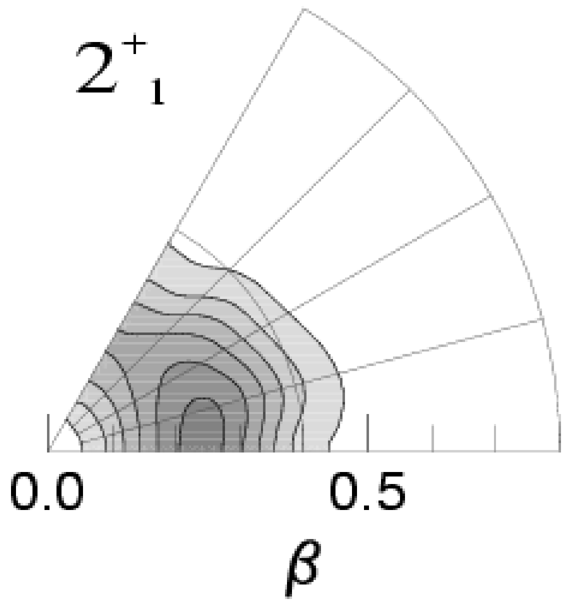
Going beyond the mean field

N=28, ^{44}S

There is no shape coexistence.
The ground state is a mixing of prolate and oblate shapes.



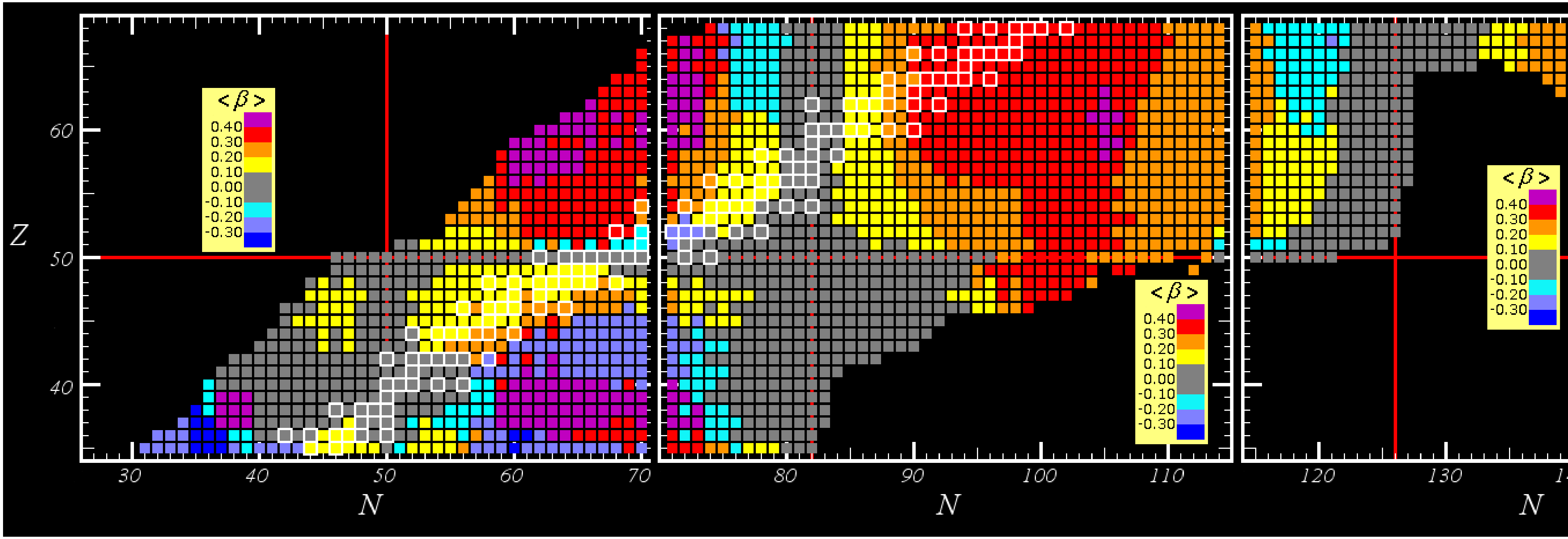
The first 2^+ state is well deformed



With "good" moment of inertia
Theo. $E(2^+_1) = 1.287$ MeV,

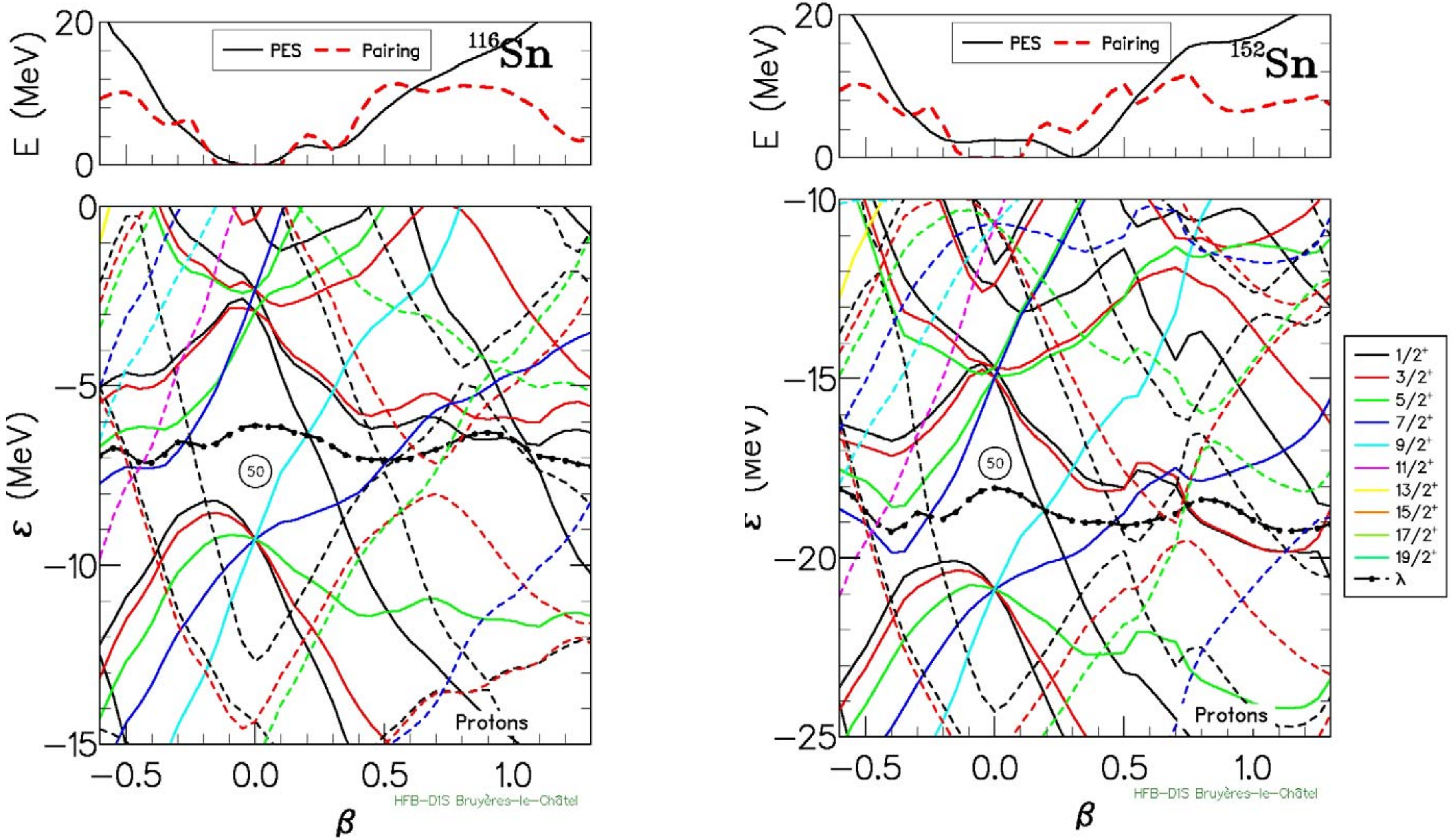
Exp. $E(2^+_1) = 1.297$ (18) MeV.

Tin isotopes



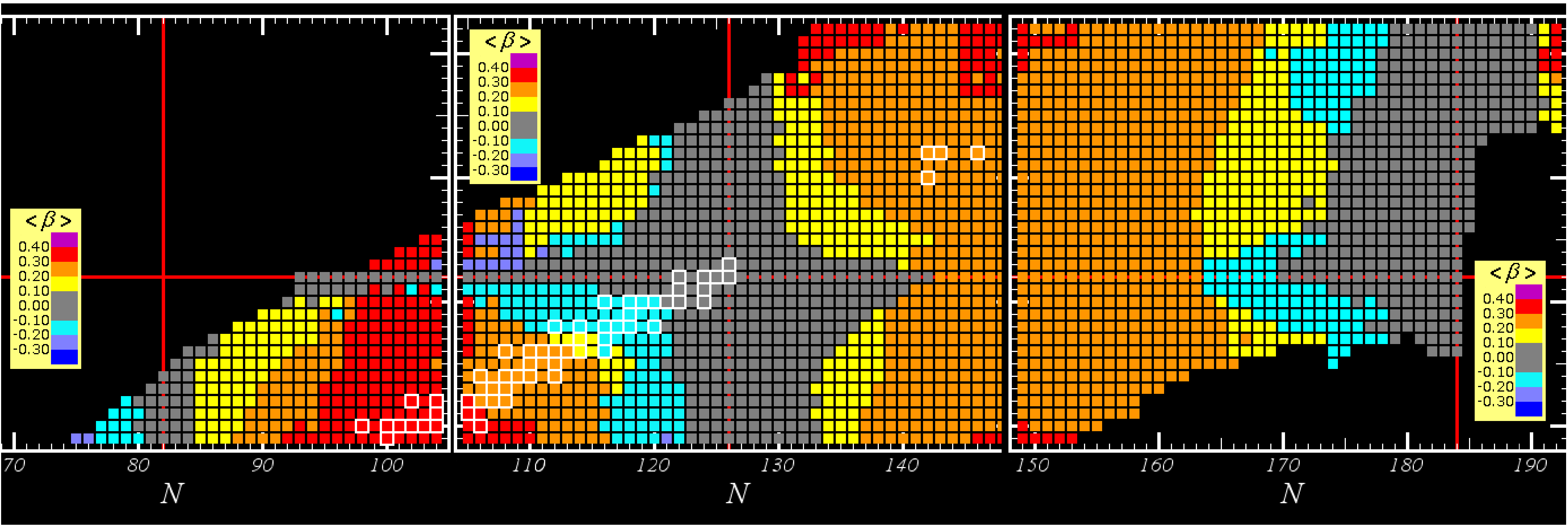
From N=97 to N=113 the Tin isotopes are predicted to be deformed

Proton gap= 6.3 MeV for N=66 and 5.9 MeV for N=102

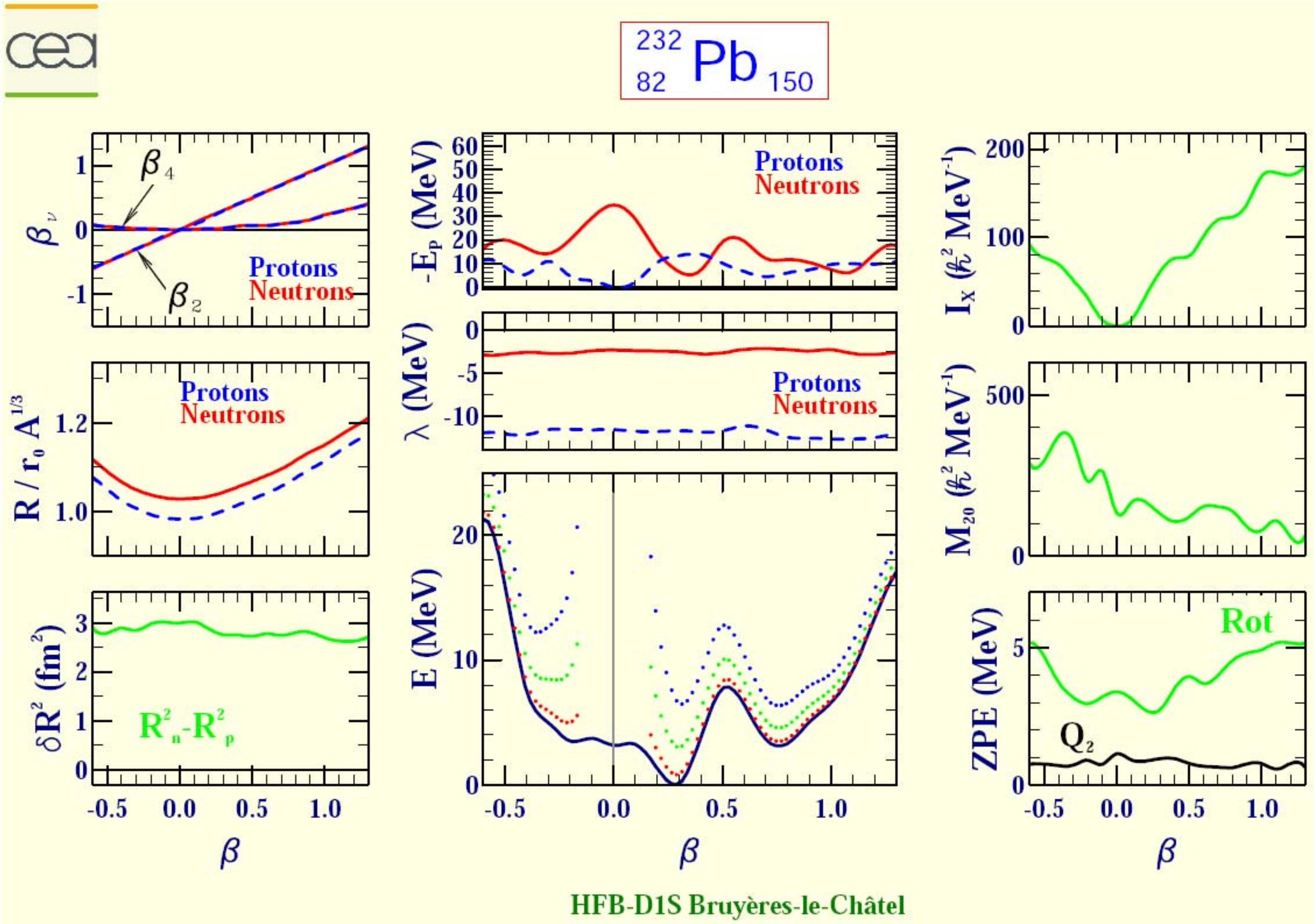


The deformation is due to the neutron shell effect

Lead isotopes



From N=143 to N=169 the Lead isotopes are predicted to be deformed



www-phynu.cea.fr/science_en_ligne/carte_potentiels_microscopiques/

Summary

N=16, subshell closure for stable nuclei
new magic number for exotic nuclei.

N=20, magic for stable nuclei, but for very exotic nuclei
the N=20 isotones are found to be dynamicaly deformed.

N=28, magic number for stable nuclei, but deformed shell closure for exotic ones.

The Gogny effective interaction fitted on nuclear matter properties
and observables of few stable nuclei
is able to give good predictons for shell evolution far from the valley of stability.

Predictions around Z = 50 and 82 are to be further challenged
with heavy neutron rich beams available in the future.