l effect changes in nuclei : the effect of n-p interacti

Shell effect evolution: A new paradigm

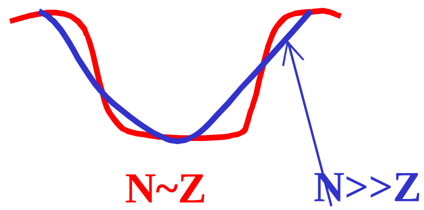
F.AZAIEZ
IPN-Orsay

Extreme N/Z ratios

Softening of the nuclear potentiel:

High-l pushed upward and

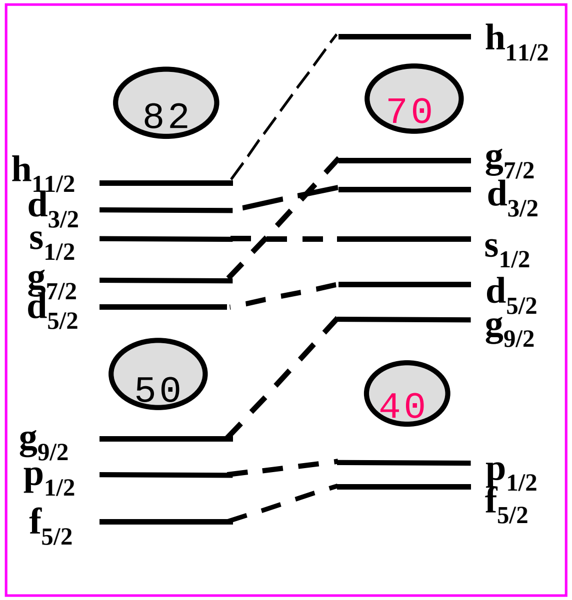
Spin-Orbit splitting reduced



Shell quenshing and reordering:

Transition from SO gaps (50,82,126)

to HO gaps (40,70,112)

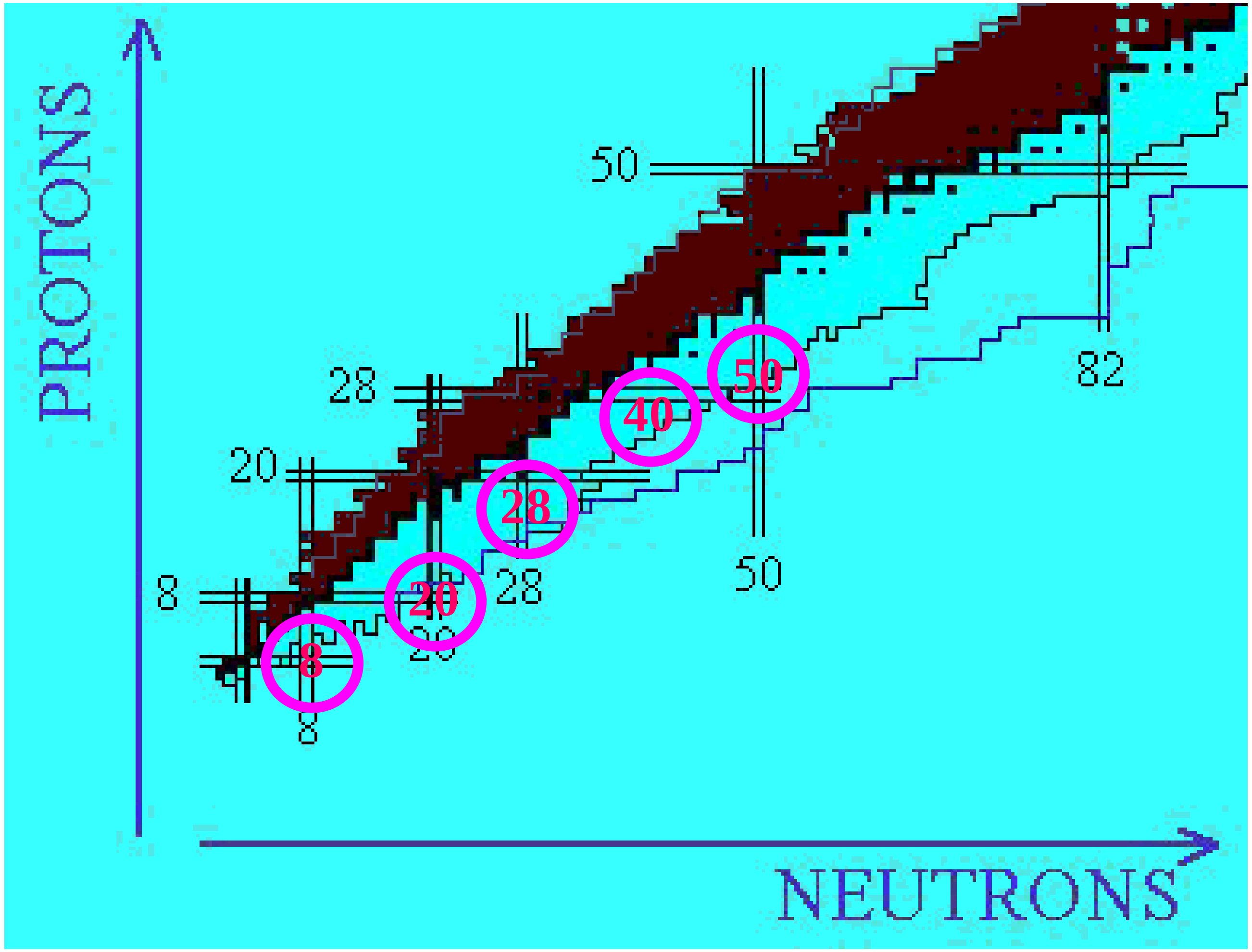


Dobaczewski et al. PRL72 (1994) 981.

None of these signature applies to the new shell structure observed in light and medium-heavy nuclei

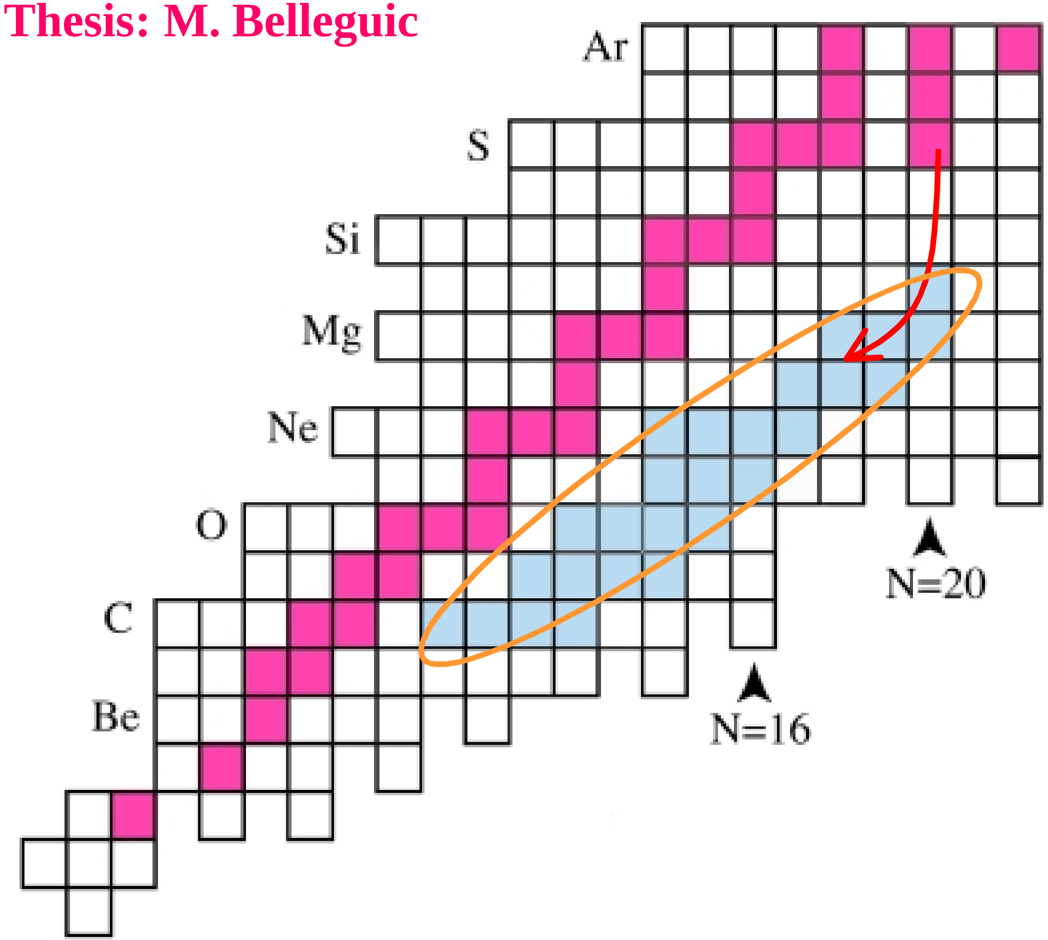
The talk will focus on :

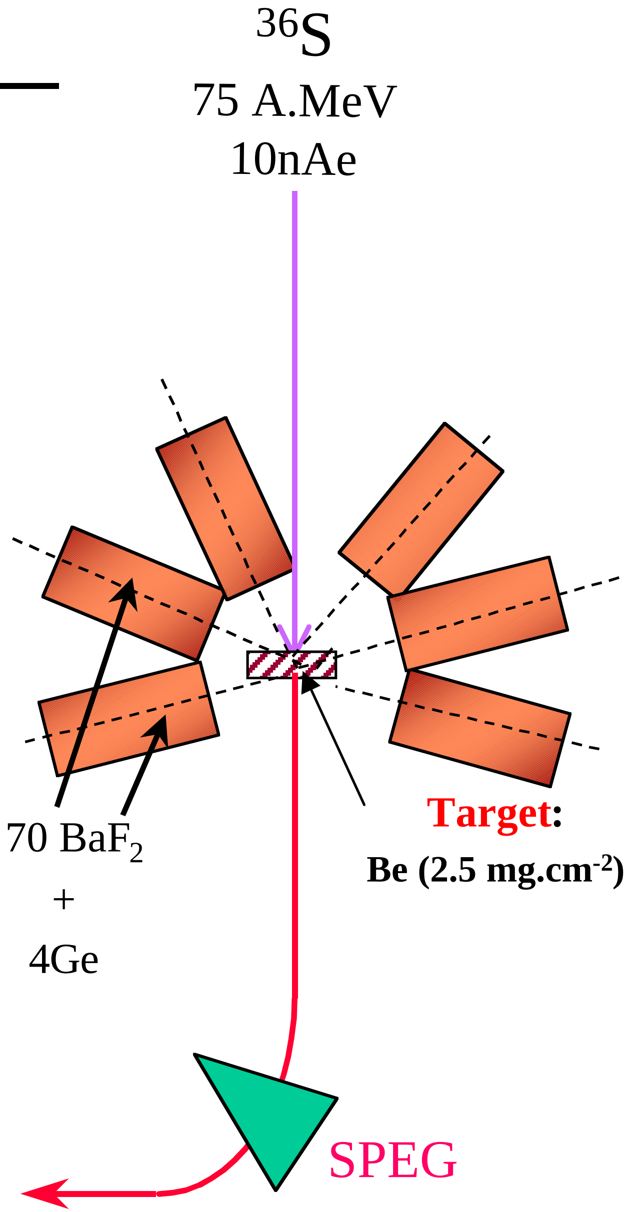
Shell structure modifications with large N/Z(around N=8,20,28,40,50)
and experimental evidence for new shells



Study of neutron-rich nuclei with **single** step in-beam fragmentation

Thesis: M. Belleguic

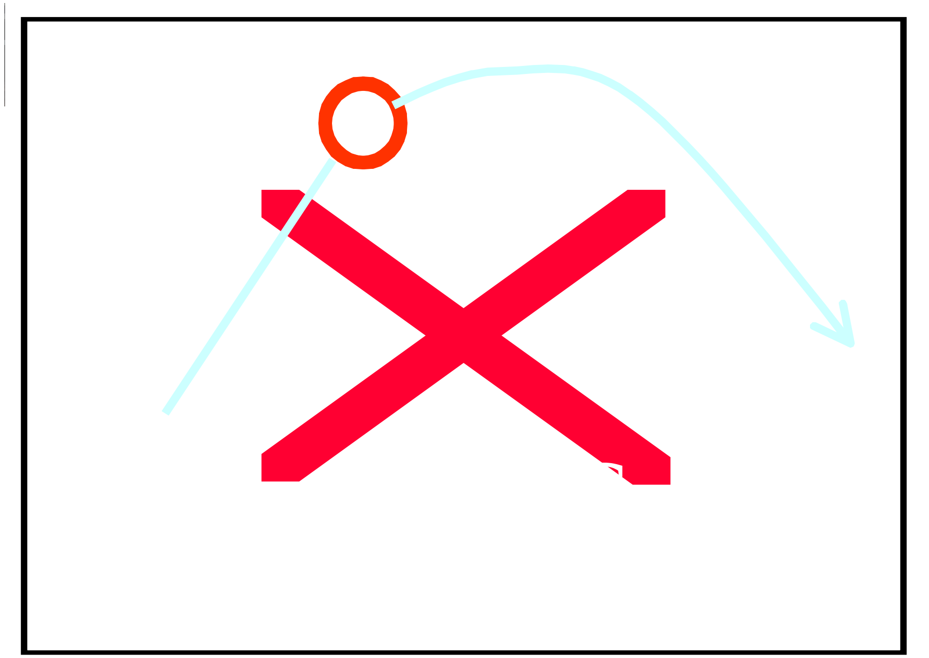




⊕ Wide range of nuclei produced by fragmentation

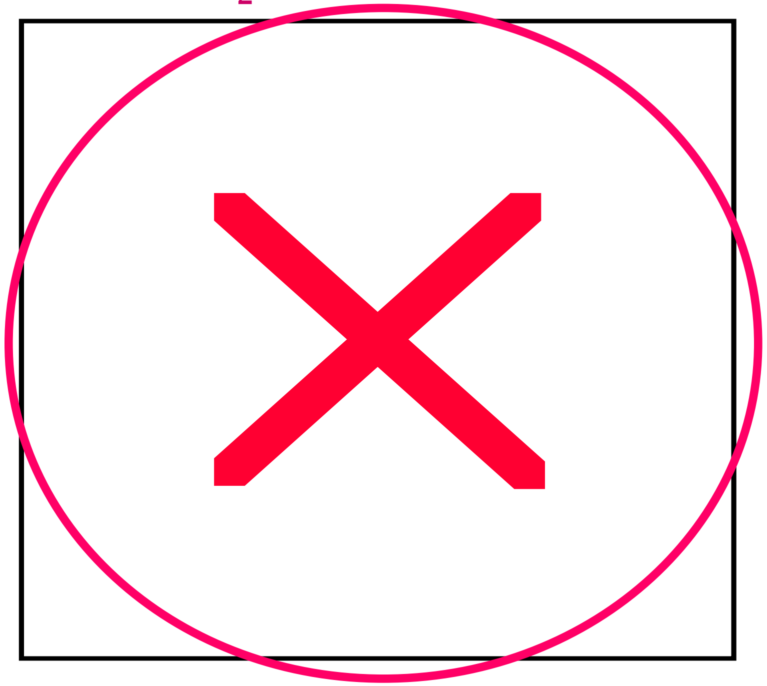
⊖ γ-detectors can withstand a limited beam intensity

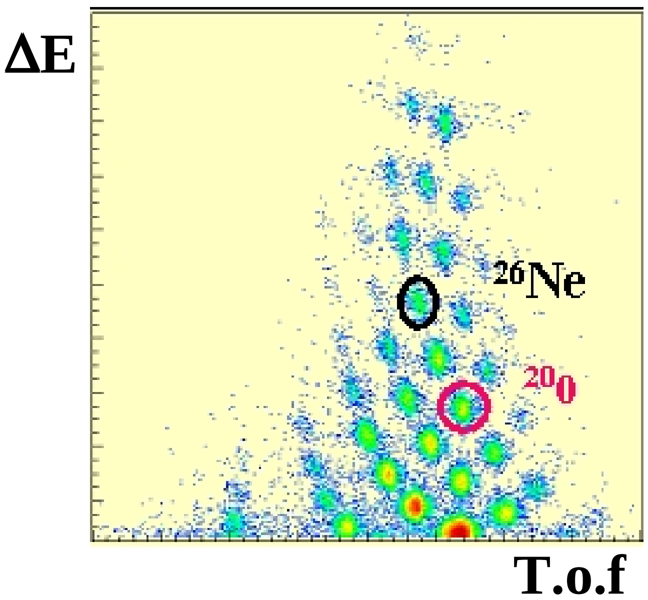
Identification of the fragments with SPEG

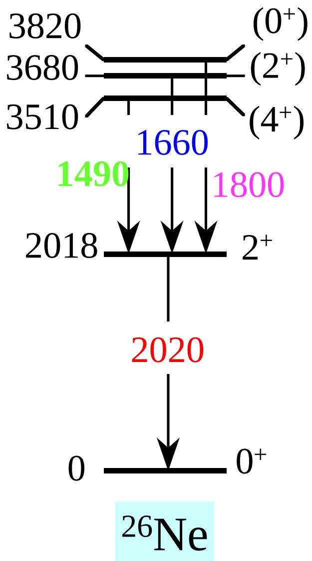


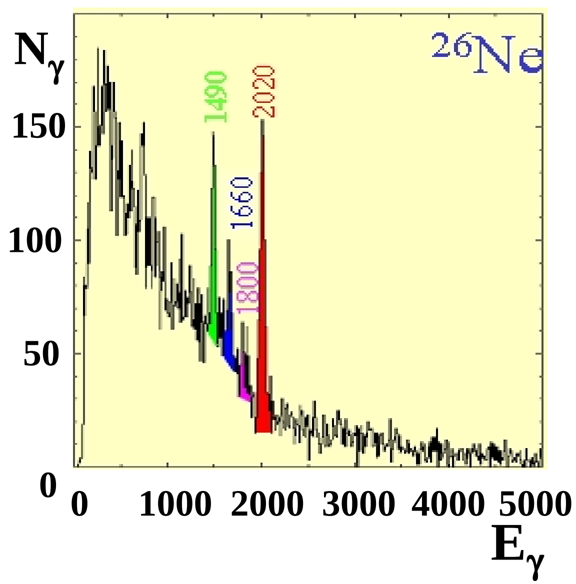
γ detection

74 BaF_2 + 4 Ge 70%



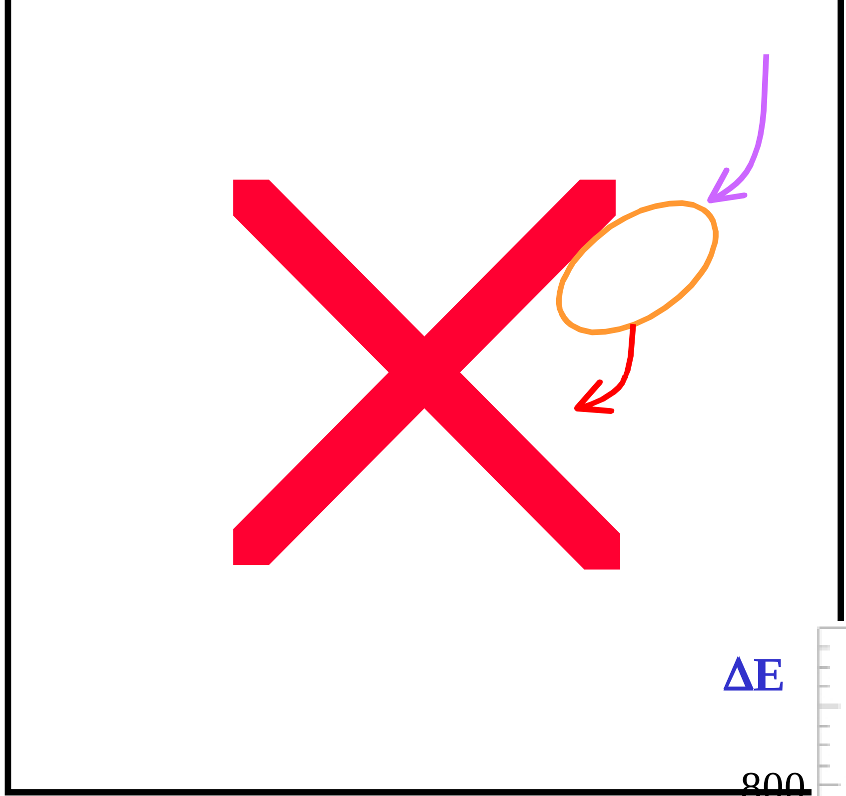


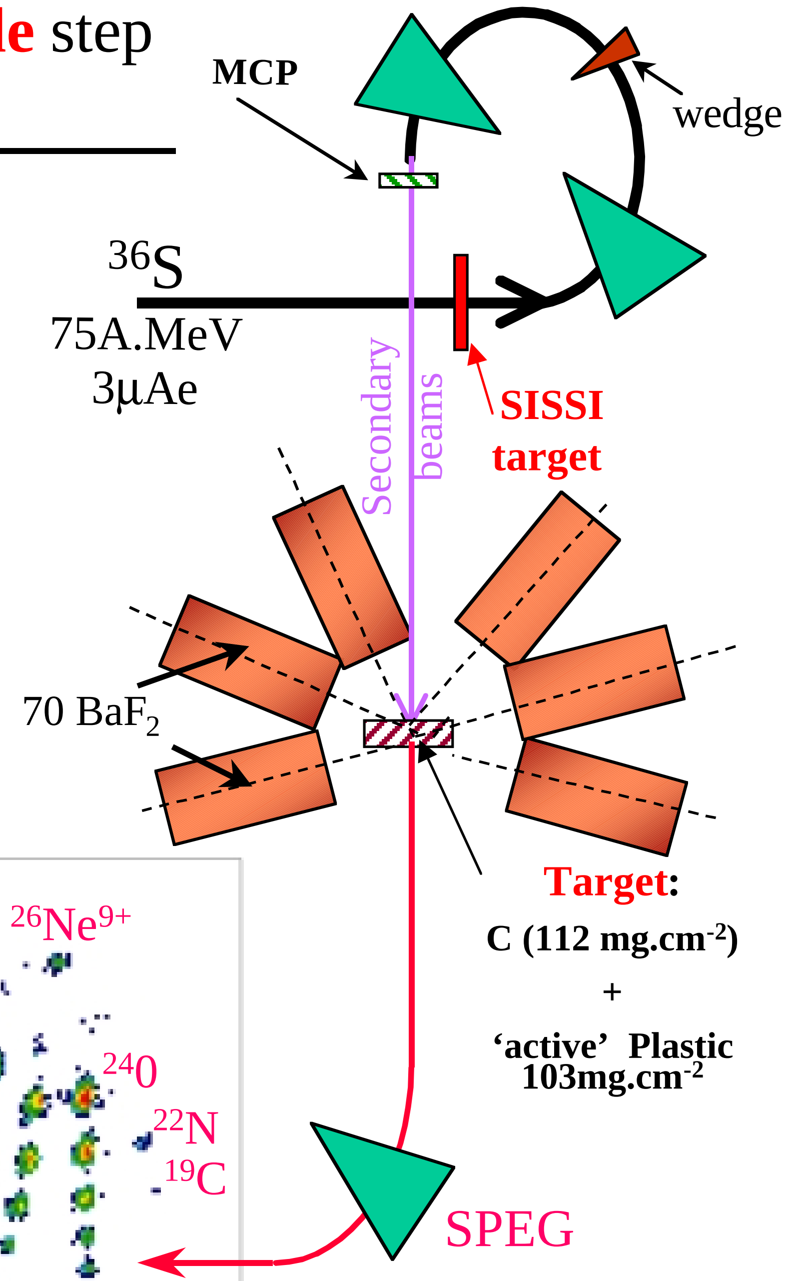


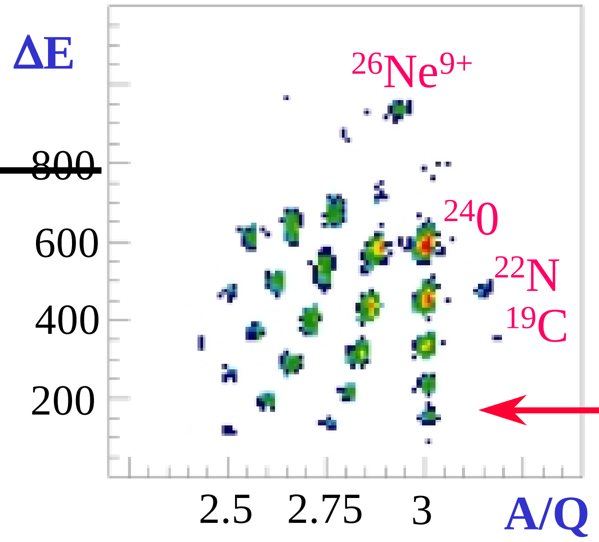


Study of neutron-rich nuclei with **double** step in-beam fragmentation

Thesis: M. Stanoiu

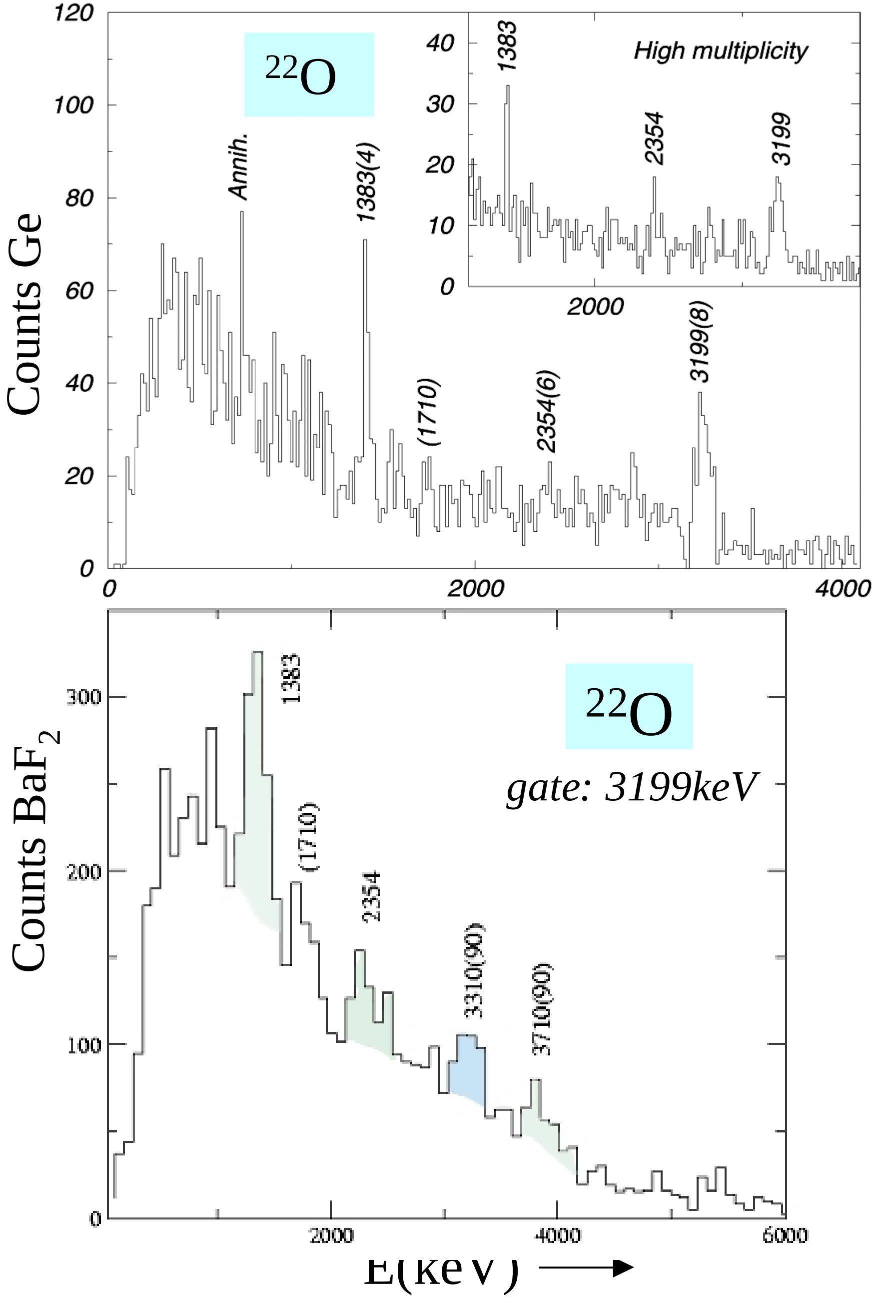


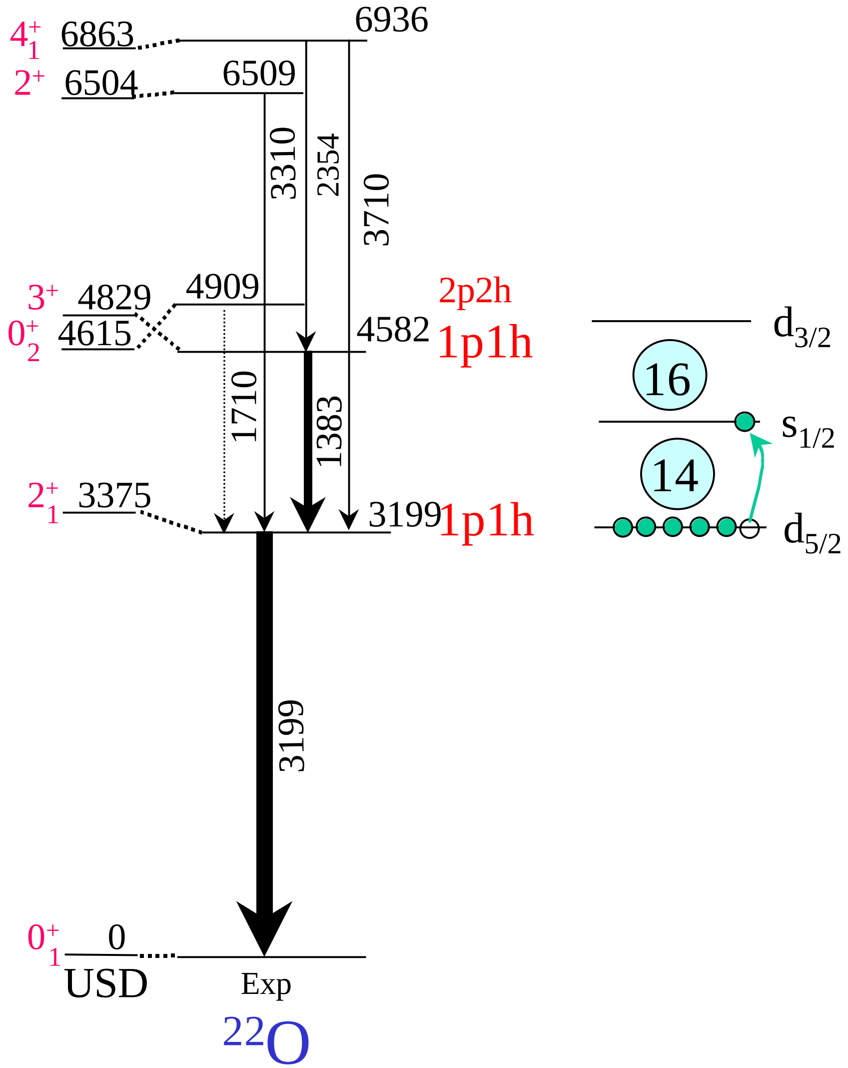




- Production rate **×10** for ^{24}O
- Better signal/noise ratio in γ-spectra
- Feeding of excited states via different projectiles

Oxygen Isotope A=22

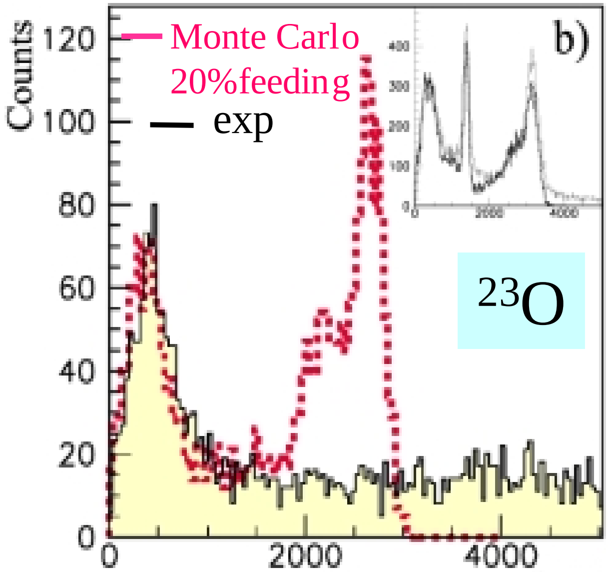


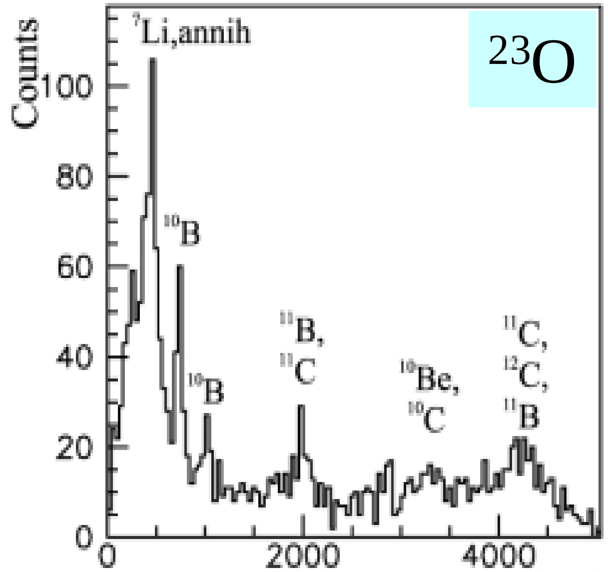


Search for bound excited states in ^{23}O and ^{24}O

(M. stanoiu et al. PRC in print)

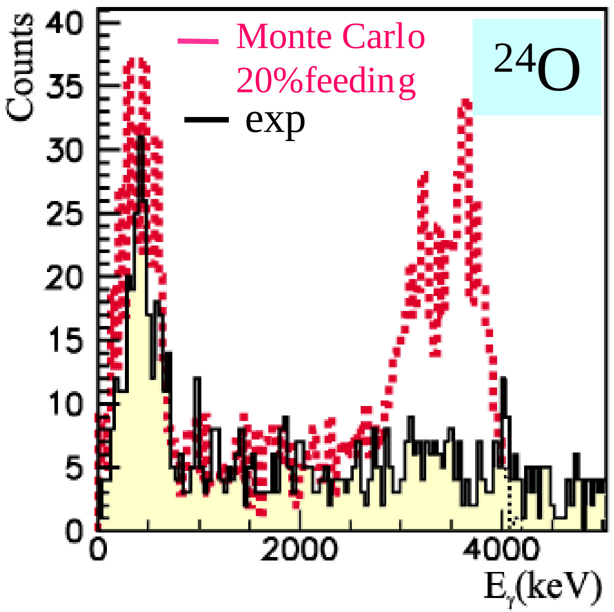
Doppler corrected

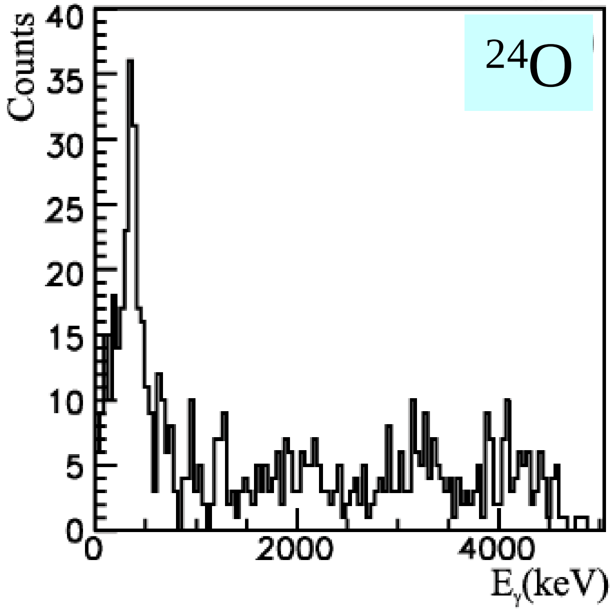




23000 nuclei

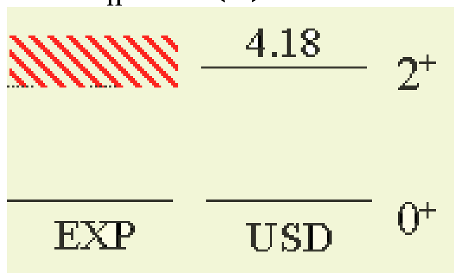
S_n= 2.7(1) MeV



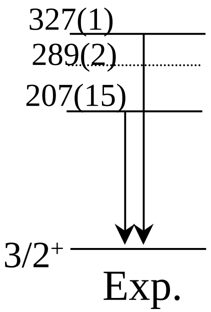


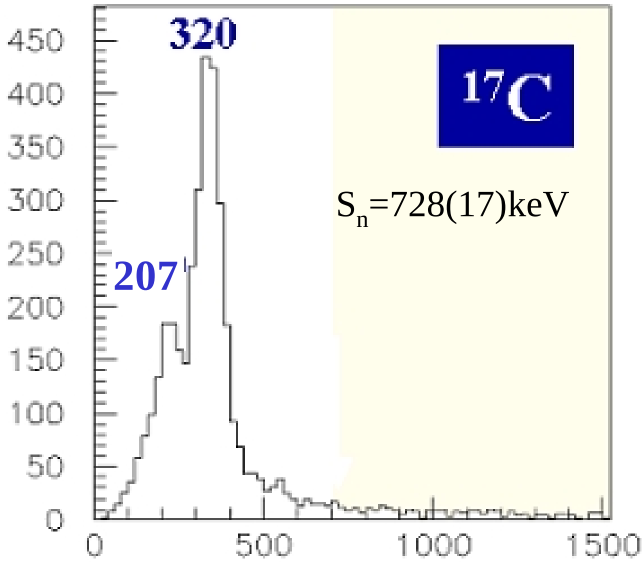
6671 nuclei

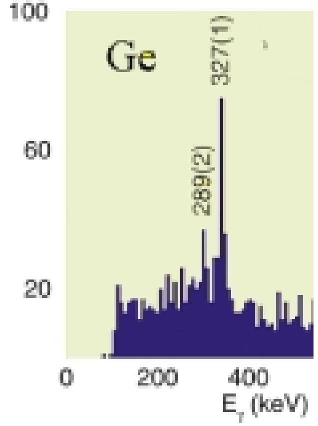
S_n=3.7(4) MeV

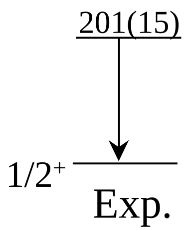


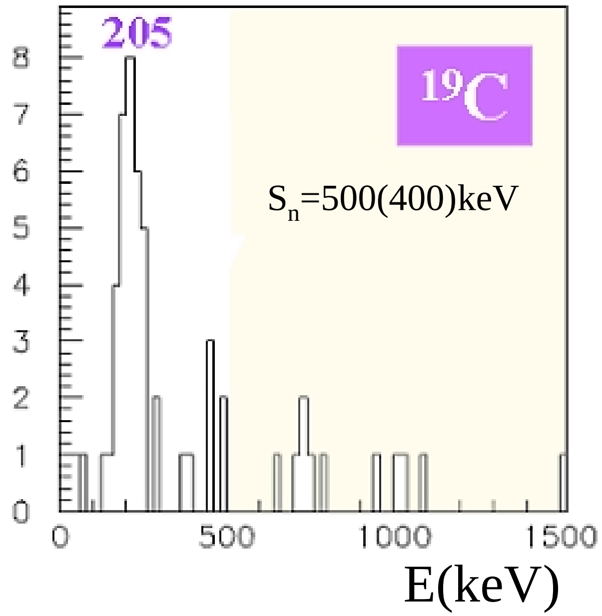
Carbon isotopes A=17,19



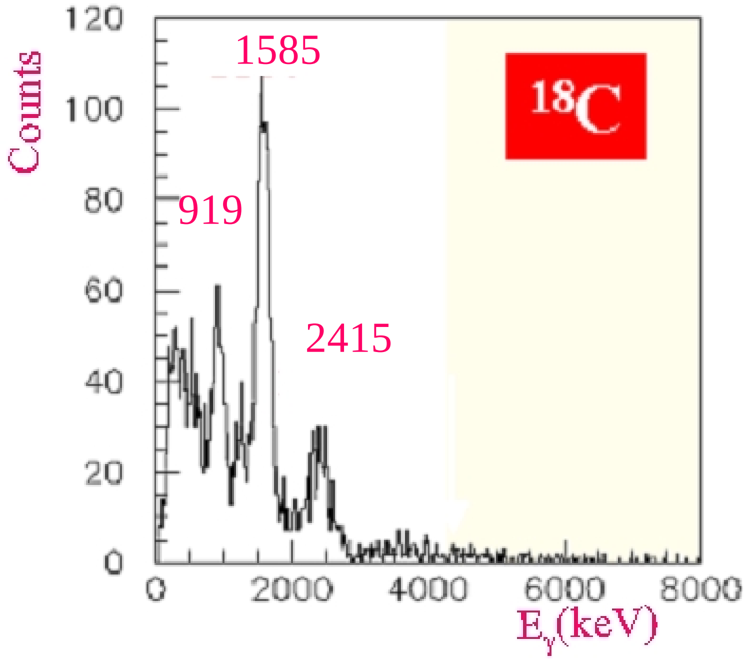


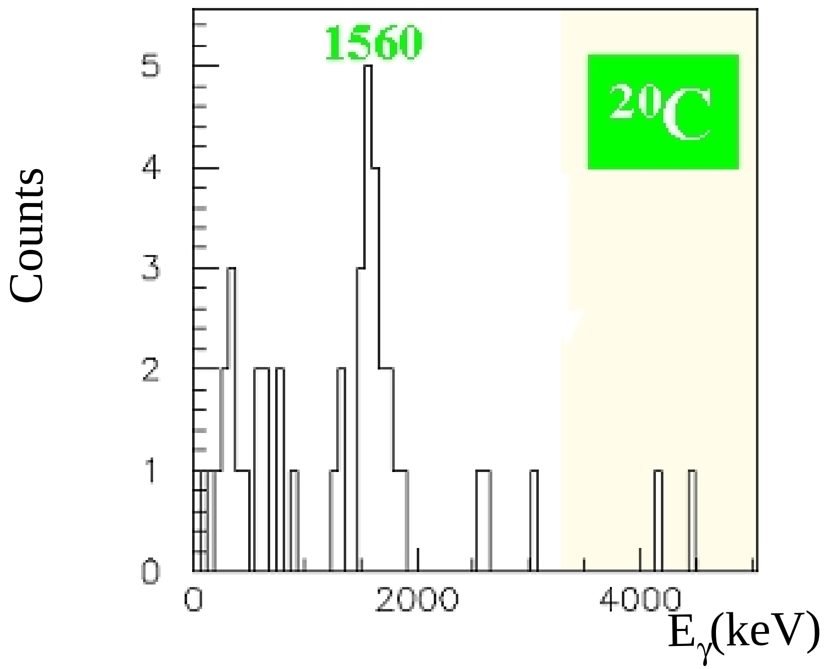


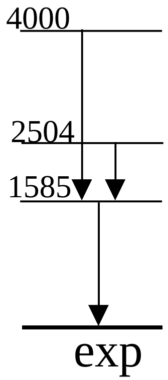


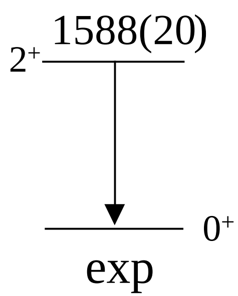


Carbon isotope A=18, 20









Collaborations:

IPN Orsay, France

GANIL, France

Nucl. Phys. Inst. Rez, Czech Republic

Inst. of Nuclear Research, Debrecen, Hungary

FLNR/JINR Dubna, Russia

NBI Copenhagen, Denmark

LPC Caen, FRANCE

IFIN Bucharest, Romania

Royal Inst. Of Technology, Stockolm, Sweden

GSI Darmstadt, Germany

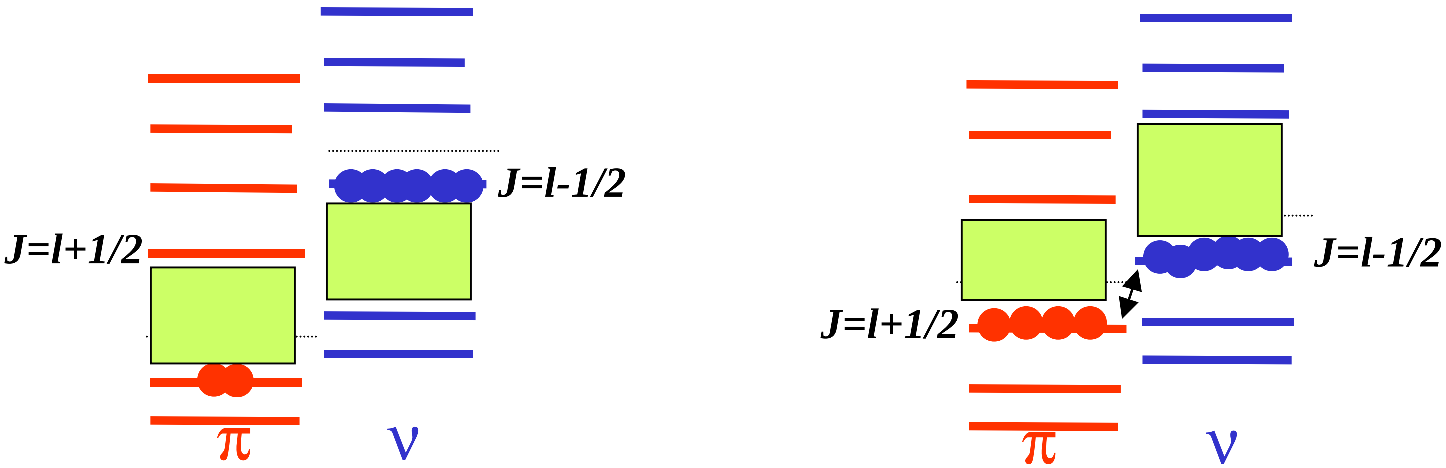
Dep. of Physics, Univ. Of Surrey, Guilford, UK

CSNSM Orsay, France

IReS Strasbourg, France,

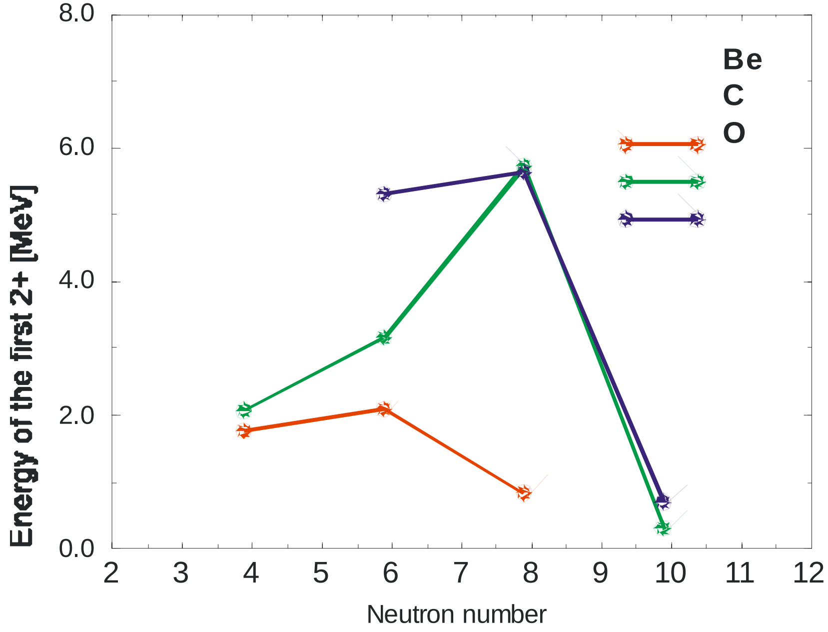
The propogation of single particle energies with increasing occupation of a major shell is governed by the monopole part of the in-medium NN interaction
E. Caurier et al. PRC 60 (1994)

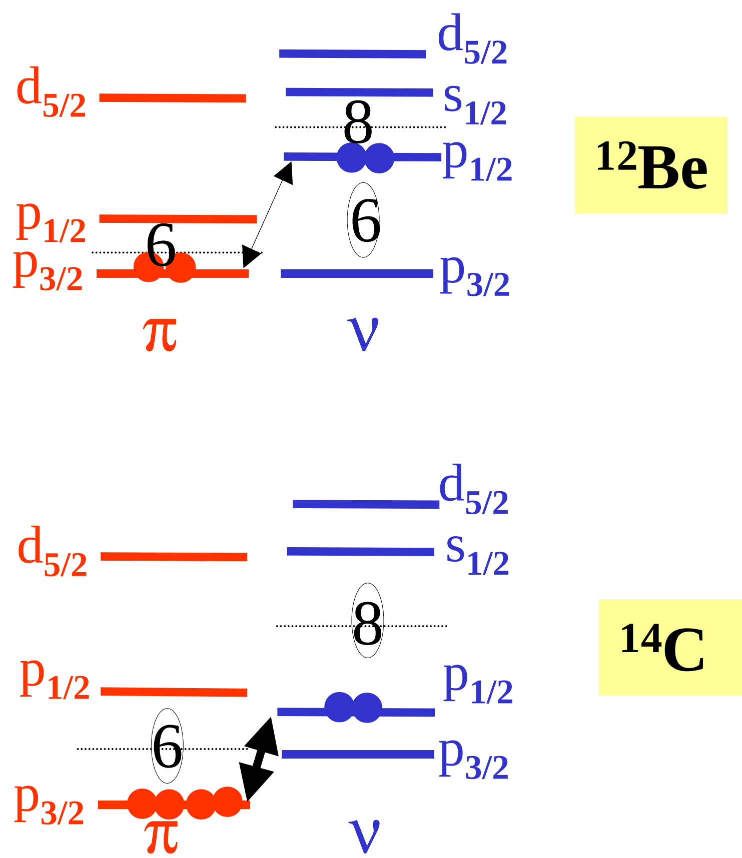
The $(\sigma.\sigma)(\tau.\tau)$ part of the in-medium NN interaction provides a schematic explanation for the n-p interaction being
-attractive!
-stronger for S=0 (spin-flip) partners and for spin-orbite partners!
Otsuka et al., PRL 87 (2001)



This n-p interaction seems to be responsible of many of the shell structure changes observed so far in neutron rich nuclei!

The example of $\pi p_{3/2}$-$\nu p_{1/2}$:
The evolution of the gaps from N=8 to N=6



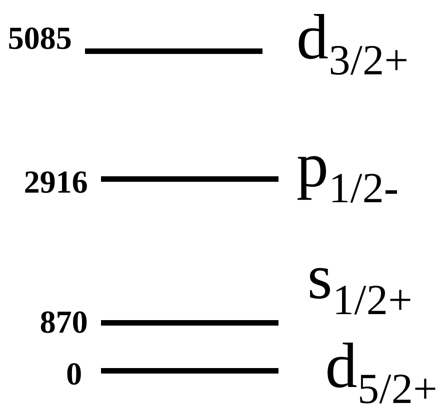


^{14}O, ^{14}C and ^{16}O: doubly magic !

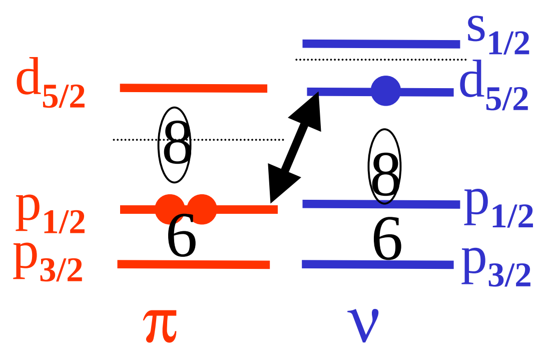
change of the shell effect from N=8 to N=6 *(^{8}He doubly magic, ^{9}Li good core for ^{11}Li) !*

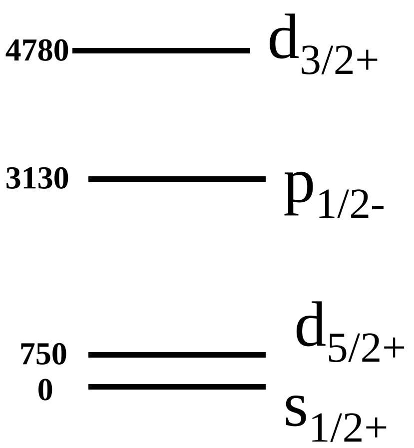
Inversion between $1/2^+$ and $1/2^-$, in ^{11}Be

The example of $\pi p_{1/2}$-$\nu d_{5/2}$(I) :

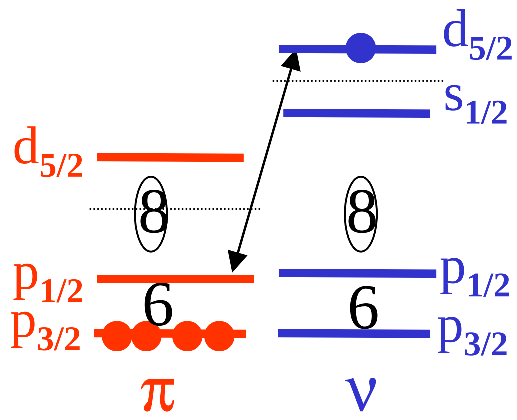


$^{17}_{8}O_{9}$





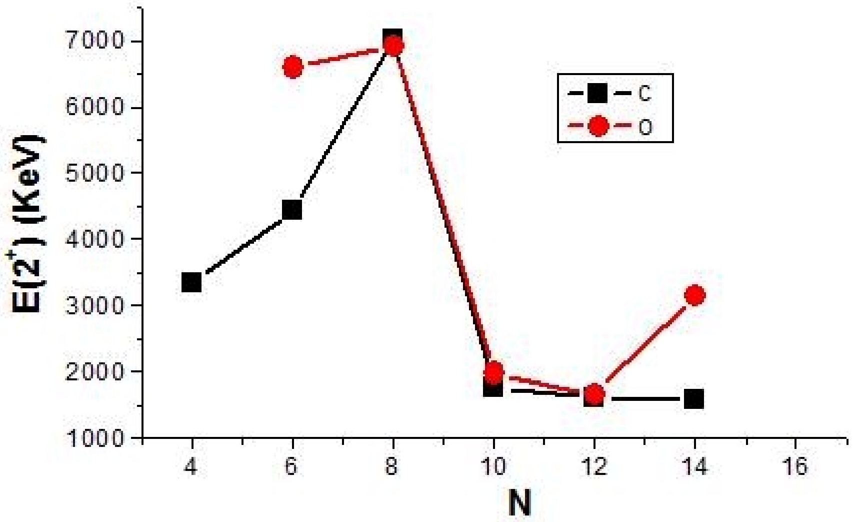
$^{15}_{6}C_{9}$



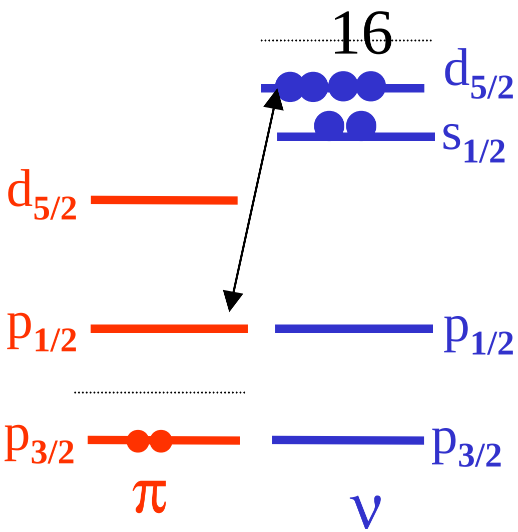
Removal of the $p_{1/2}$ proton from ^{16}O releases the neutron S=0 partner $d_{5/2}$ consequently the $5/2^{+}$ and the $1/2^{+}$ states swap positions from ^{17}O to ^{15}C

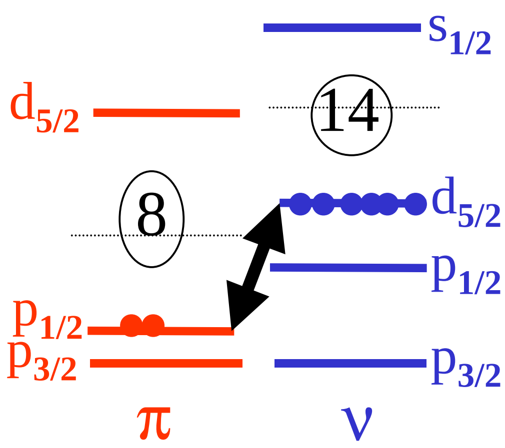
The example of $\pi p_{1/2}$-$\nu d_{5/2}$ (II):

(M. Stanoiu et al. In preparation)



$^{20}_{6}C_{14}$

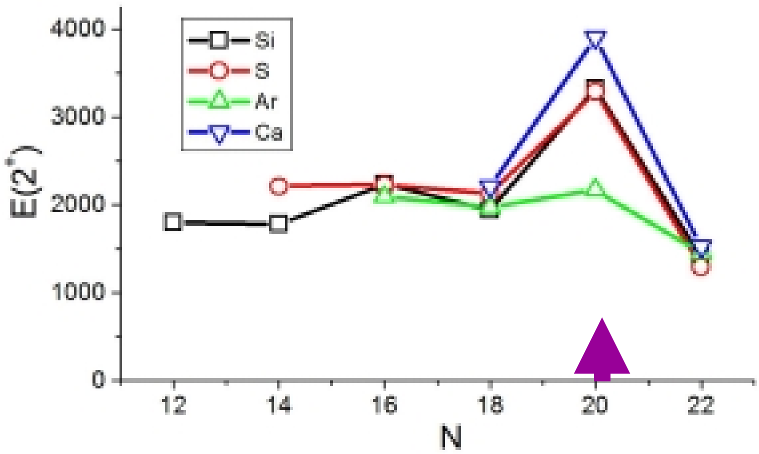


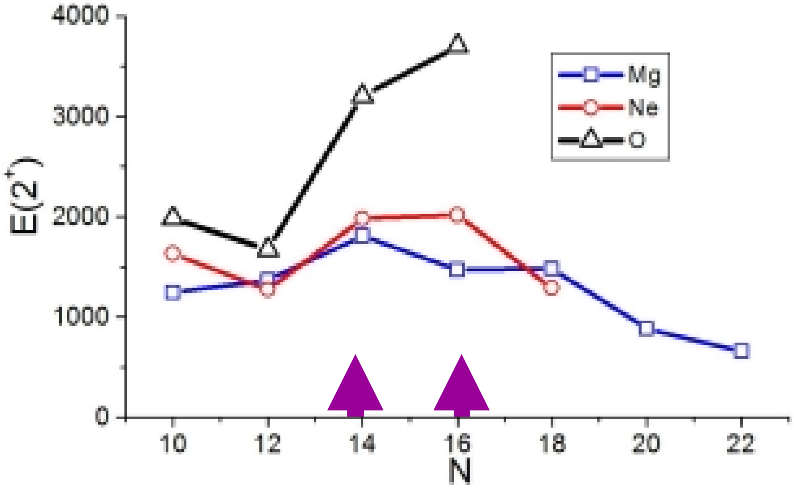


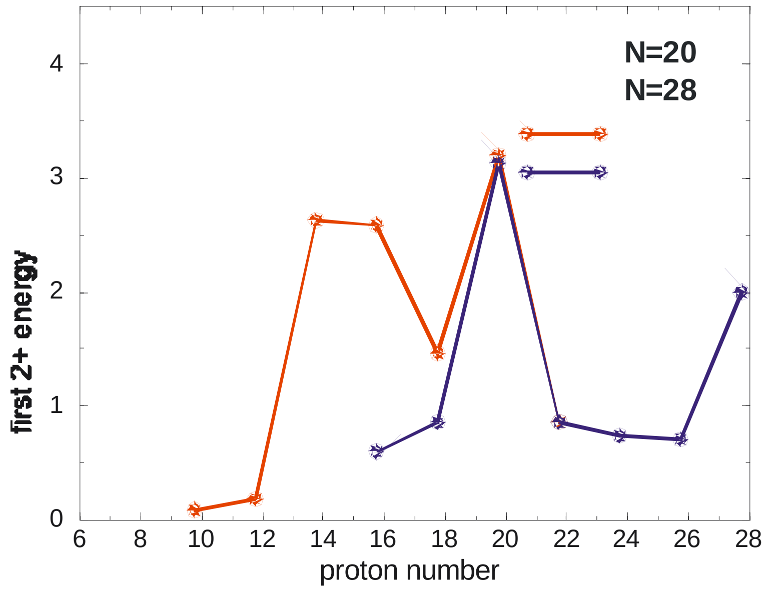
$^{22}_{8}O_{14}$

Explains the diffrence between ^{20}C (midd-shell nucleus) and ^{22}O (doubly magic nucleus)

The example of $\pi d_{5/2}$-$\nu d_{3/2}$:
The 'isle of inversion' and the neutron gaps evolution from N=20 to N=14 (16)

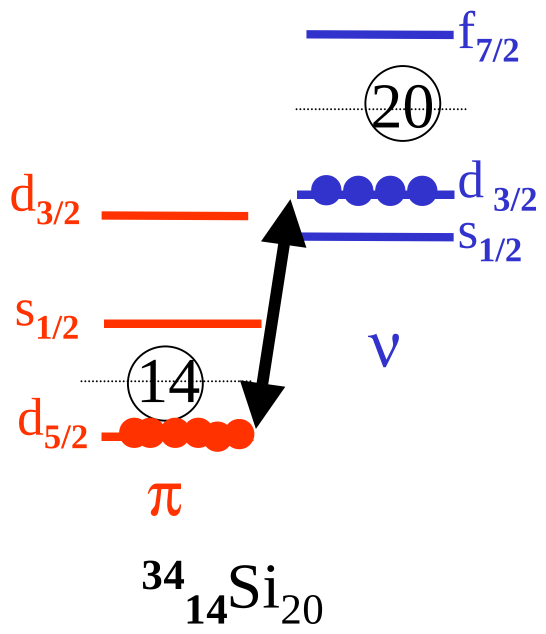


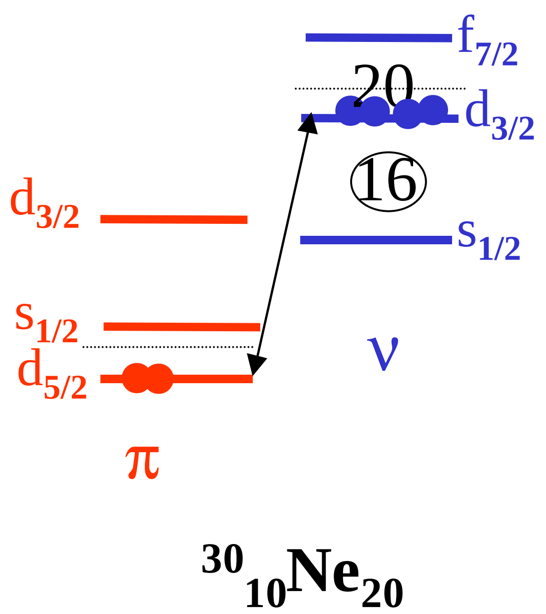




A dramatic increase of the 2+ energy in $^{34}_{14}Si$ and $^{36}_{16}S$

The example of $\pi d_{5/2}$-$\nu d_{3/2}$:
The isle of inversion and the neutron gaps evolution from N=20 to N=14 (16)

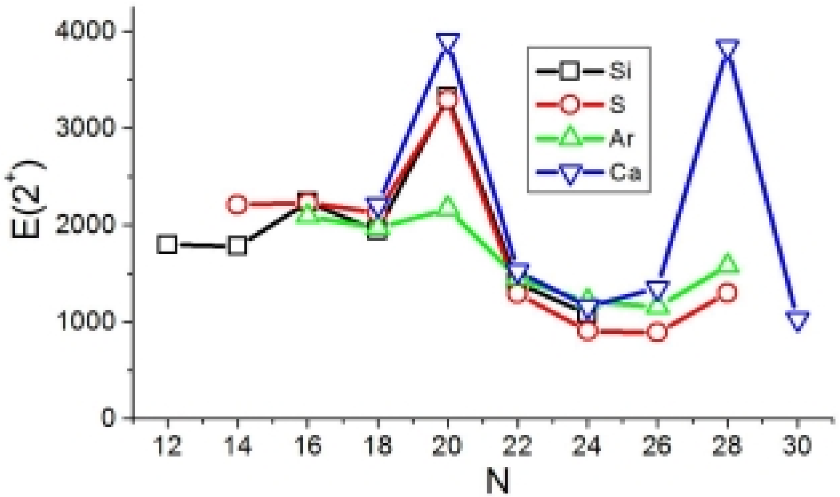


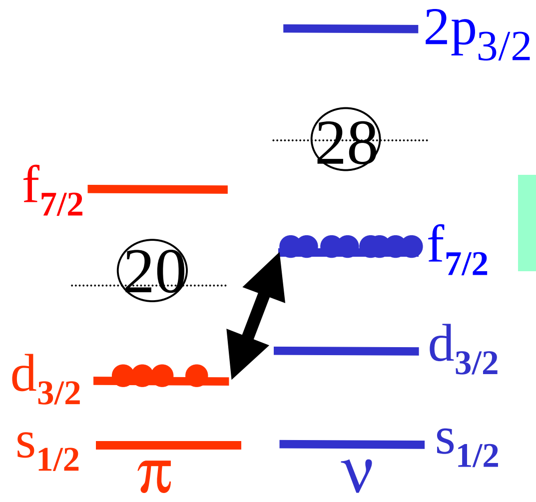


^{34}Si and ^{36}S doubly magic!
^{34,36} Ca should be similar!
(a challenge :
next experiment at GANIL)

The evolution from N=20 to N=14/16 'the isle of inversion' (There must be the mirror 'isle of inversion' around ^{36} Ca)

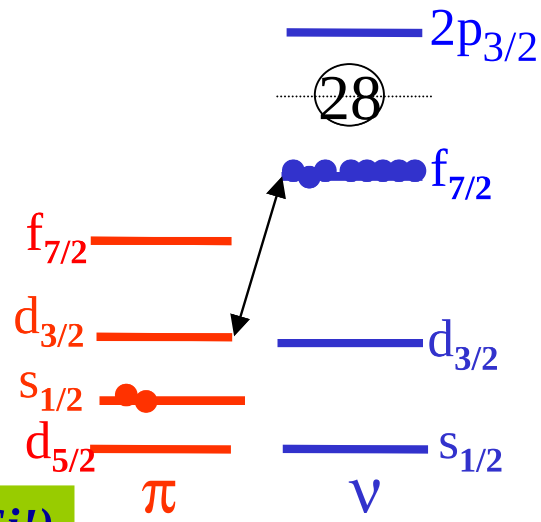
The example of $\pi d_{3/2}$-$\nu f_{7/2}$ interaction : The evolution of N=28





^{48}Ca

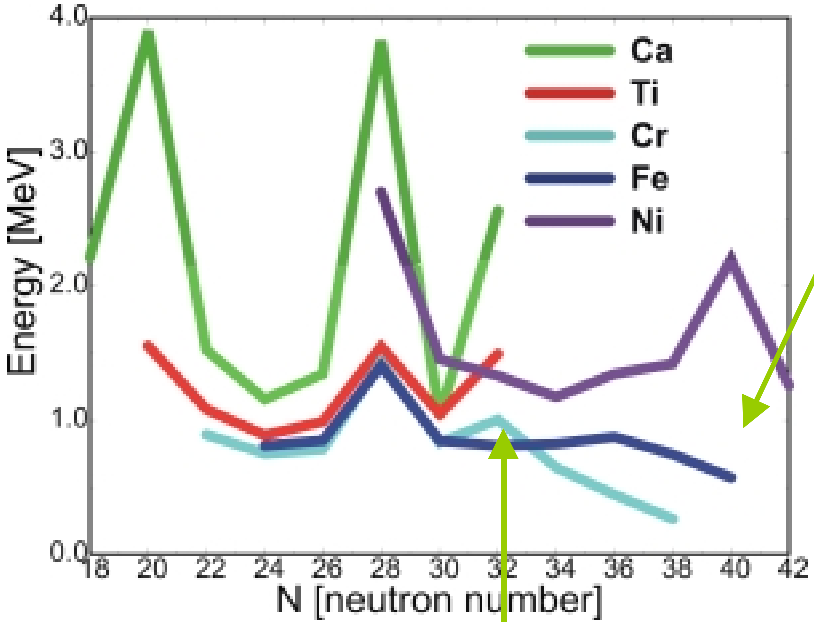
Going from Ca and Ar to S , 2+ energy decreases and quadrupole collectivity sets in!



^{44}S

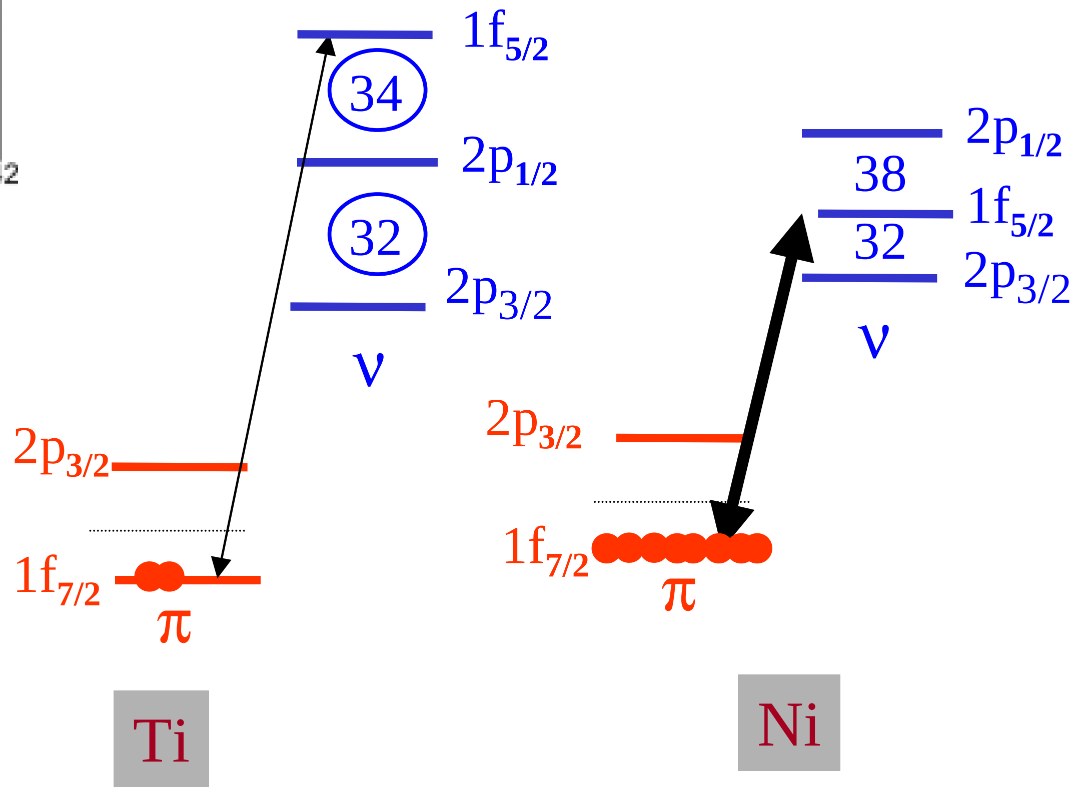
This effect should continu when protons are in the $d_{5/2}$ (^{42}Si!)

The case of $\pi f_{7/2}$-$\nu f_{5/2}$ interaction: the evolution towards the N=32 (34) gaps

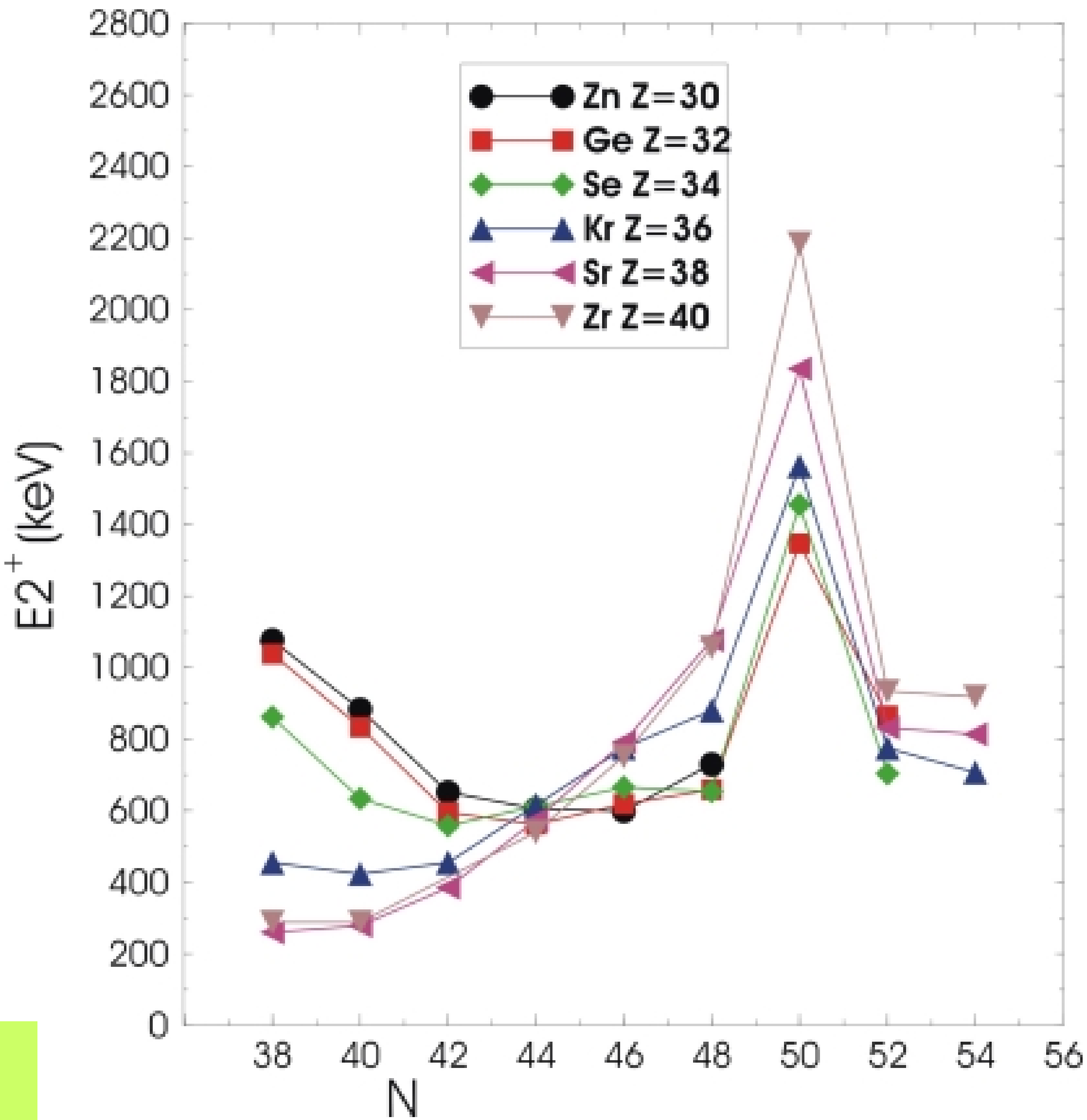


The HO closed shell N=40 in ^{68}Ni is weak and disappears quickly by removing pairs of protons.

Going from Ni to Ca (while emptying the $f_{7/2}$ proton) new gaps at N=32 (34) appear!



The evolution of N=50!



No π–ν interaction scheme can account for any sizeable reduction of the N=50 !!

Challenge:Extend the systematics

of the 2^+ energies around N=50

ALTO-SPIRAL2

Just measure and see!!!

Up to N=50 n-p interaction can account <u>qualitatively</u> for new shell structure

Neither large scale shell model nor mean field calculations have predicted this in shell structure

Realistic interactions used in large scale shell model account poorly for the monopole strength and need an 'ad hoc' corrections.

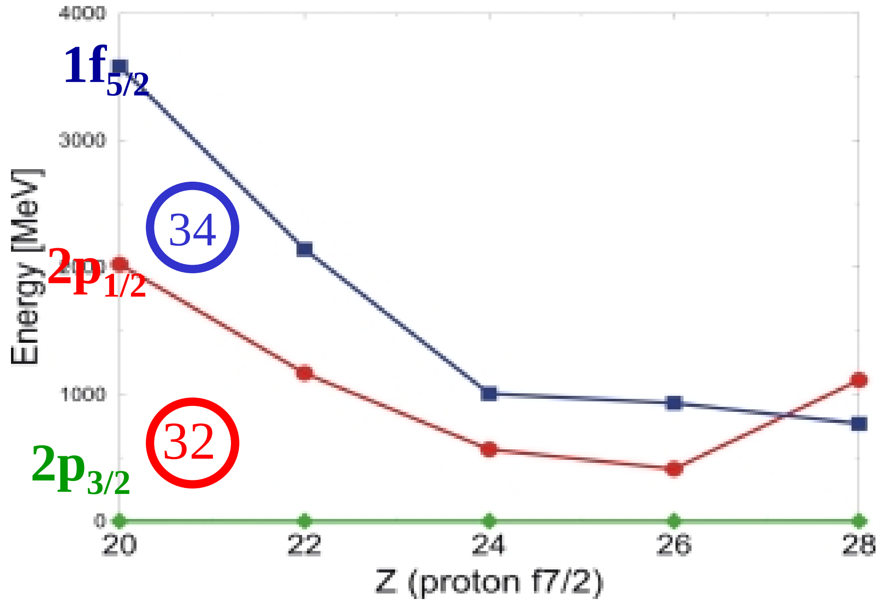
For mean field interactions it has been argued that they may fail to account for the $(\sigma.\sigma)(\tau.\tau)$ part of the NN interaction

Need to measure the strength of this interaction:
Evolution of the s.p energies and spectroscopic factors!

Evolution of the single neutron energies in the N=29 isotones from Ca to Ni (while filling the $\pi f_{7/2}$).

The effect seems to be there!!

But….



In the future: **The evolution of the $d_{3/2}$ neutron when filling the $d_{5/2}$ proton using transfer reactions with RNB**

Neutron-particle states in N=15 isotones and neutron-hole states in N=19 isotones of O, Ne, Mg and Si