Evolution of deformation in neutron-rich Cr isotopes

S.M.Lenzi, A.Gadea, A.Dewald

and

AGATA Collaboration

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Laboratori Nazionali di Legnaro

AGATA ADVANCED GAMMA TRACKING ARRAY

Proposal

It is proposed to study the lifetime of excited states in the neutron-rich nuclei ^{58,60,62}Cr to investigate the shape evolution towards the new region of deformation around N=40 and to get a better understanding of the nuclear structure in this mass region.

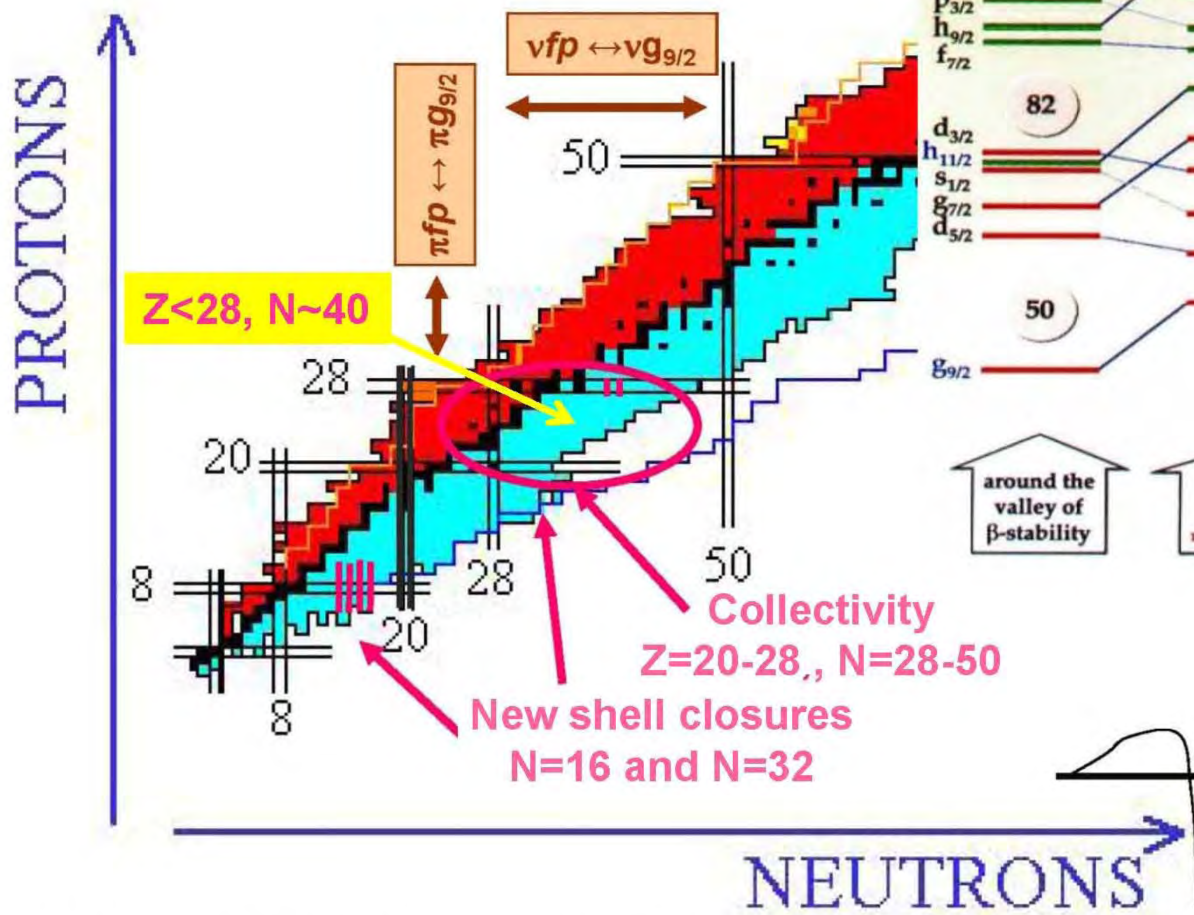
Outline of this presentation

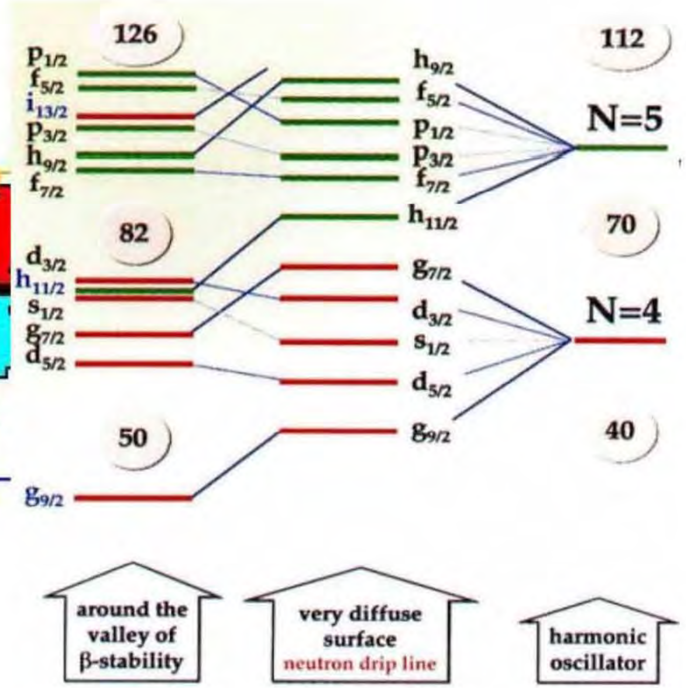
- ^{58}Cr and the critical point of the shape-phase transition E(5)
- Heavier Cr isotopes: ^{60,62}Cr
- Experimental Conditions

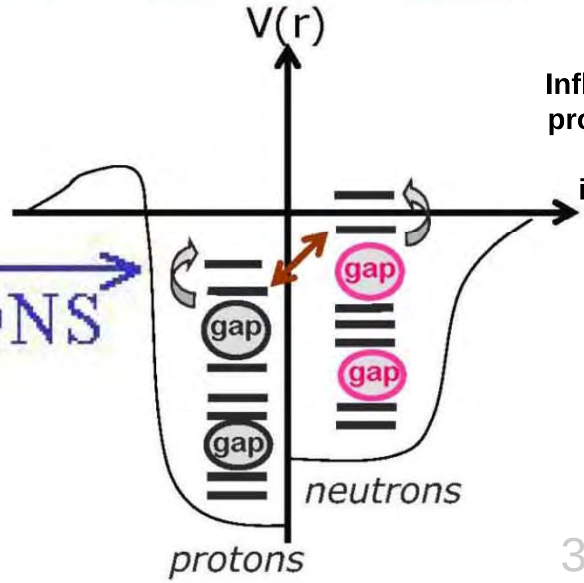
New insights into the nuclear structure far from stability

Neutron excesses and new shell gaps

Consequences in nuclear dynamics and astrophysics



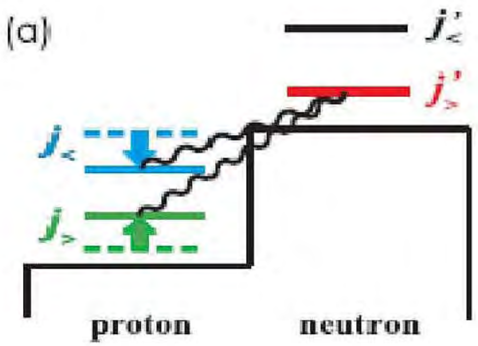


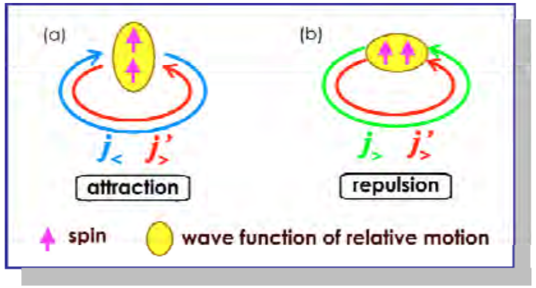


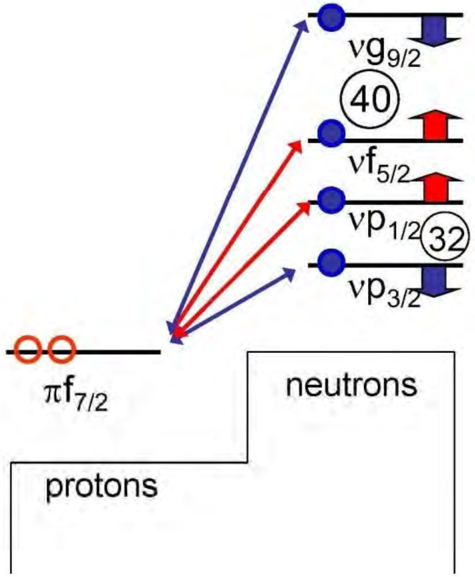
Influence of the proton-neutron monopole interaction

Shell gap modifications signatures: masses, E(2$^+$), B(E2), γ spectroscopy, single particle energies,…
<u>role of</u>: valence nucleons (through n-p interaction), pairing (residual interactions)

Orbital migrations - Proton-neutron spin-flip interaction





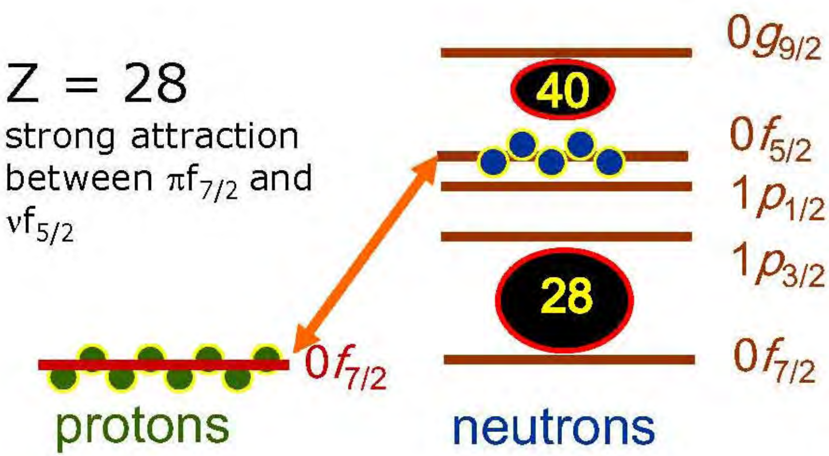


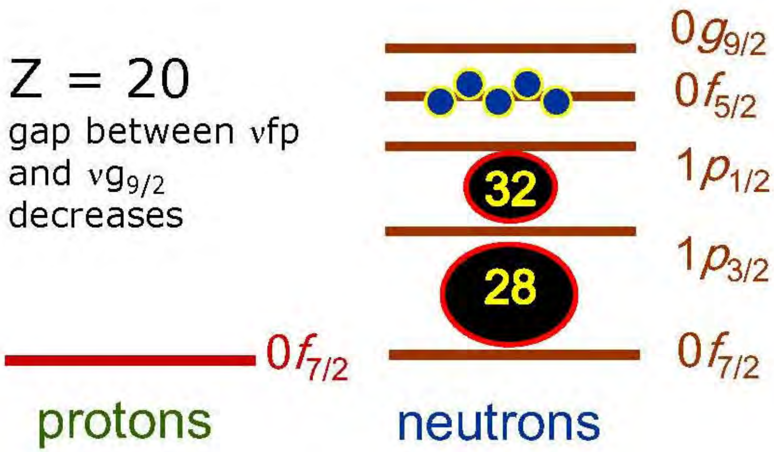
$$V_T = \tau \cdot \tau \left([\sigma \cdot \sigma]^{(2)} \cdot Y^{(2)} \right) f(r)$$

Monopole tensor term of the p-n interaction

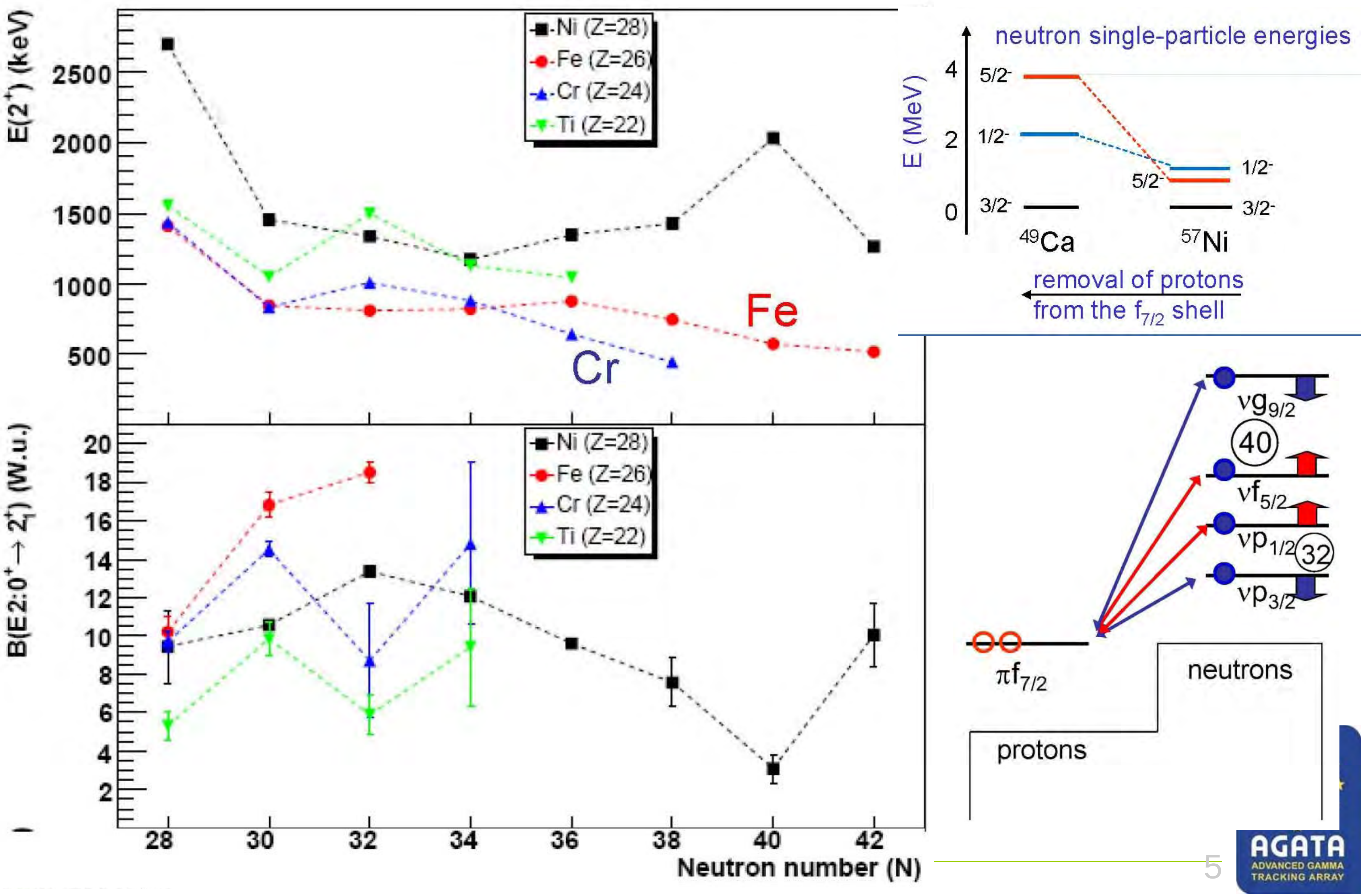
T. Otsuka et al., PRL 95 (2005) 232502

removing protons from the $f_{7/2}$ shell



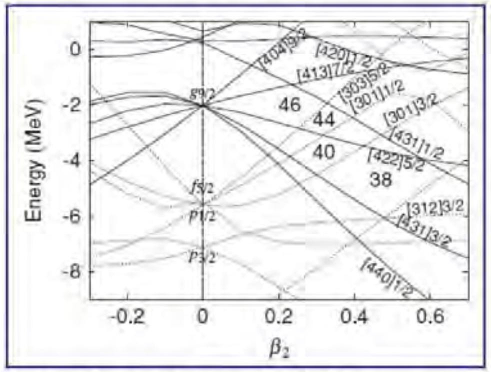


Collectivity and p number in n-rich nuclei for Z<28



Collectivity in n-rich Cr isotopes

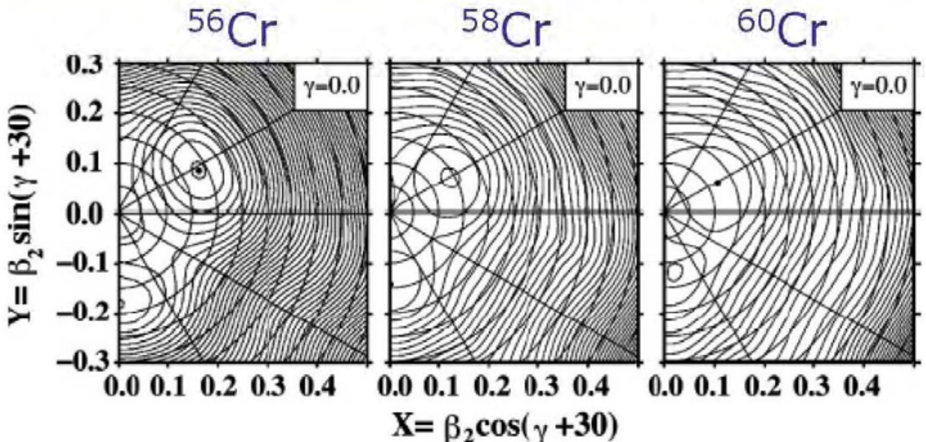
single particle energies in a deformed WS potential



K. Yoshida and M. Yamagami, PRC 77, 044312 (2008)

Ground-state potential energy surfaces (TRS)

S. Zhu et al., PRC 74, 064315 (2006)

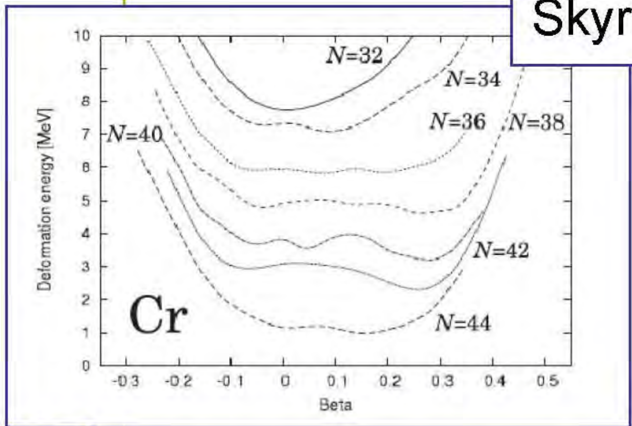


Total Routhian Surface

For large N values Cr isotopes exhibit γ softness and deformation

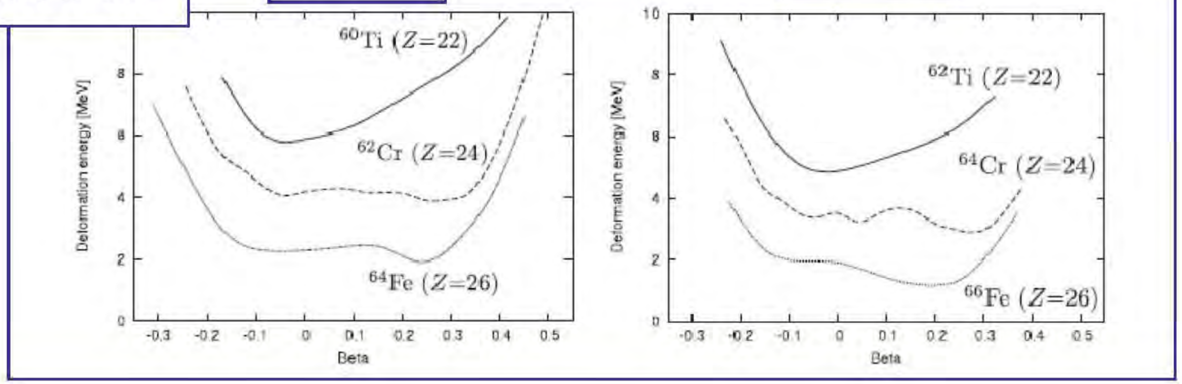
Mean Field Calculations

Skyrme-HFB

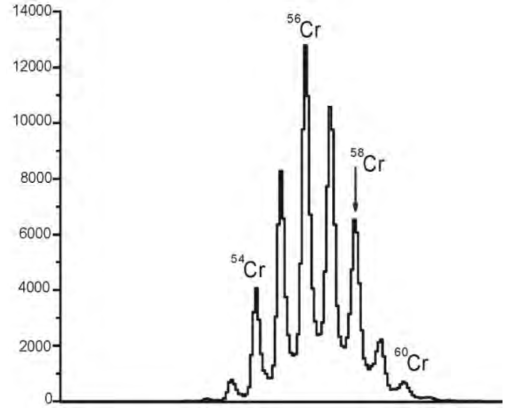


N=38

N=40



Spectroscopy of heavy Cr isotopes at LNL



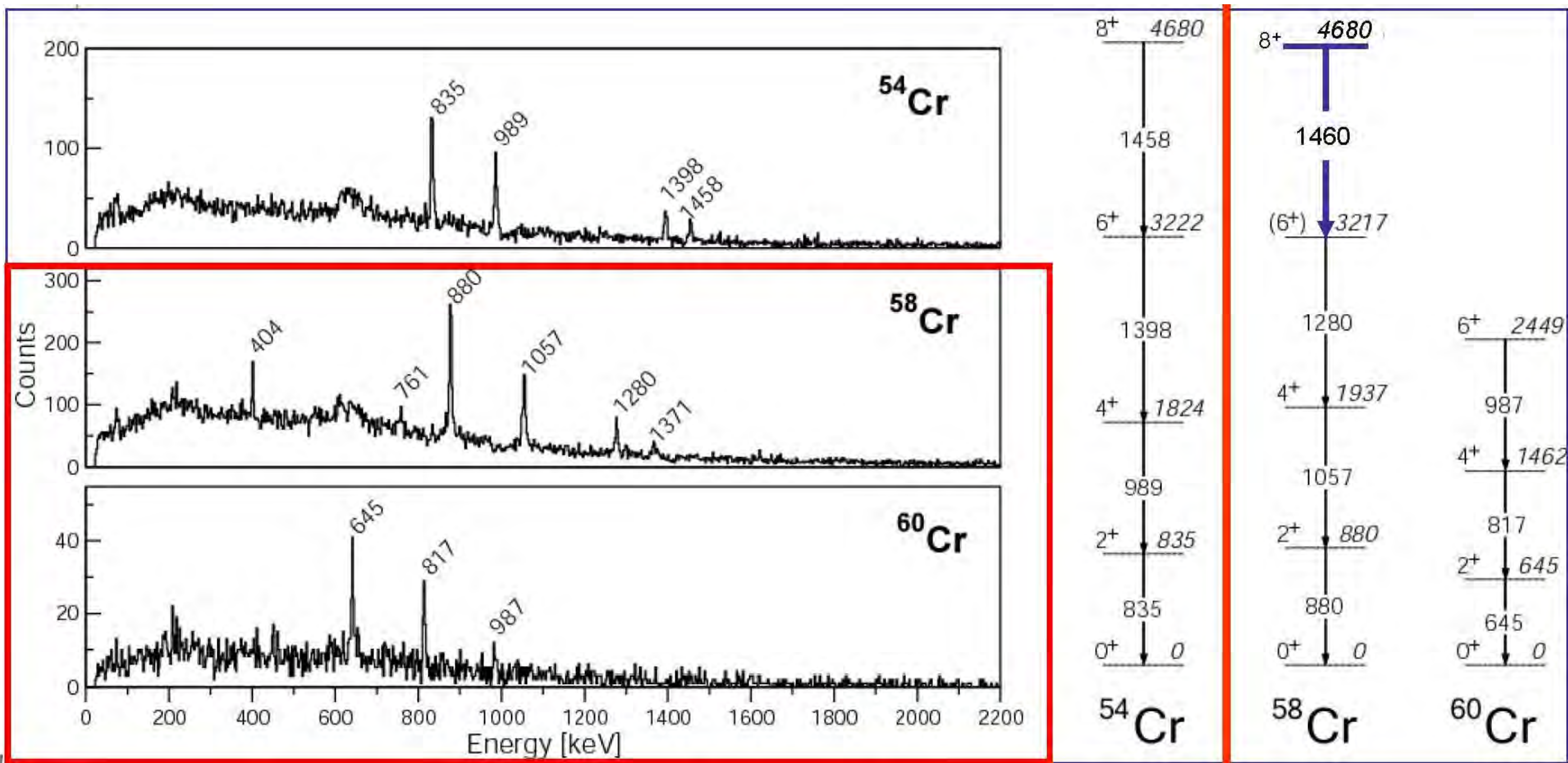
^{64}Ni + ^{238}U at E_L = 400 MeV

- ^{58}Cr: 880, 1057 and 1280 in mutual coincidence.

880 and 1057 stretched quadrupole transition, from g anisotropy (Clara 100° and 150° /180°).

404 and 761 couldn't be placed.

- ^{60}Cr shows a more collective level scheme. The further decrease of the E2$^+$ for ^{62}Cr [Sorlin et al., EPJ A16 (2003) at GANIL] points to the evolution of even-even Cr towards deformed regime at N=40.



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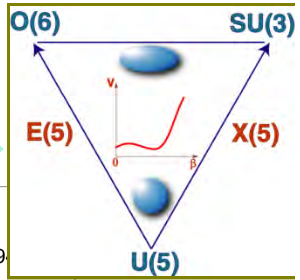
^{58}Cr and the shape phase transition critical point



E(5) Dynamical Symmetry candidate

VOLUME 85, NUMBER 17 PHYSICAL REVIEW LETTERS 23 OCTOBER 2000

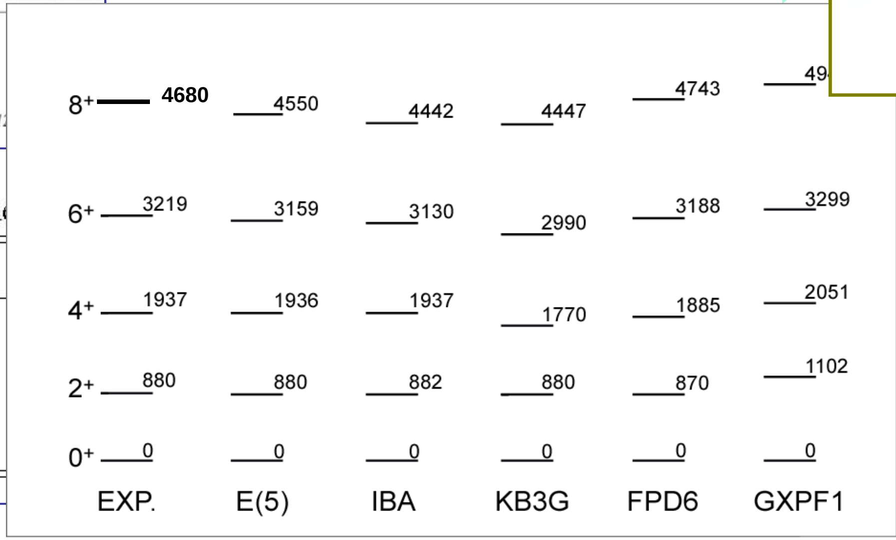
Dynamic Symmetries at the Critical Point

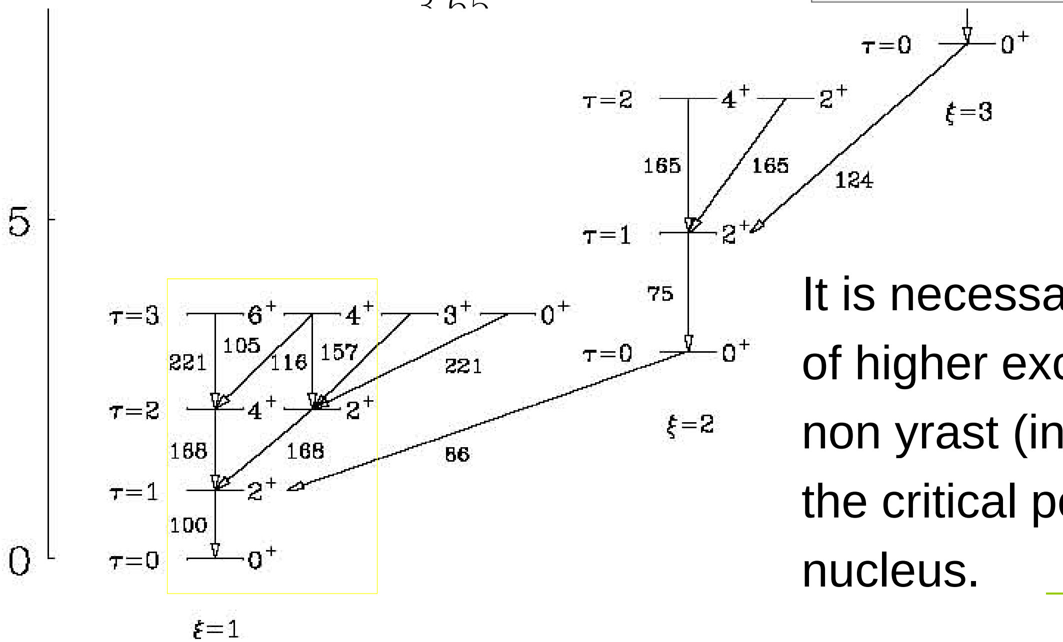
F. Iachello
Center for Theoretical Physics, Sloane Laboratory, Yale University, New Haven, Connecticut 06520-81
(Received 8 May 2000)

TABLE 1. Excitation energies of the E(5) symm

	$\xi = 1$	$\xi = 2$	$\xi = 3$
$\tau = 0$	0		7.58
$\tau = 1$	1		11
$\tau = 2$	2.20		86
$\tau = 3$	3.59		81
$\tau = 4$	**5.17**		

^{58}Cr:
E_{4+}/E_{2+} = 2.20
E_{6+}/E_{2+} = 3.65



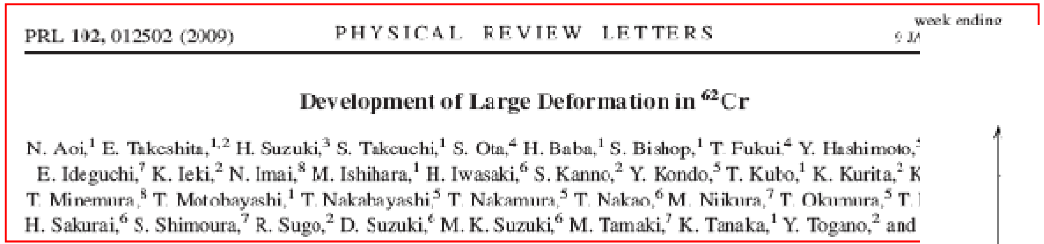


Recently at RISING:
B(E2: 2+->0+) = 14.8(4.2) W.u.
Good agreement with theory

It is necessary to measure the lifetimes of higher excited states (up to 8+?) and non yrast (in particular the 2^+_2) to test the critical point character of this nucleus.

Deformation in Heavier Cr Isotopes: ^{60,62}Cr

Proton inelastic scattering in inverse kinematics

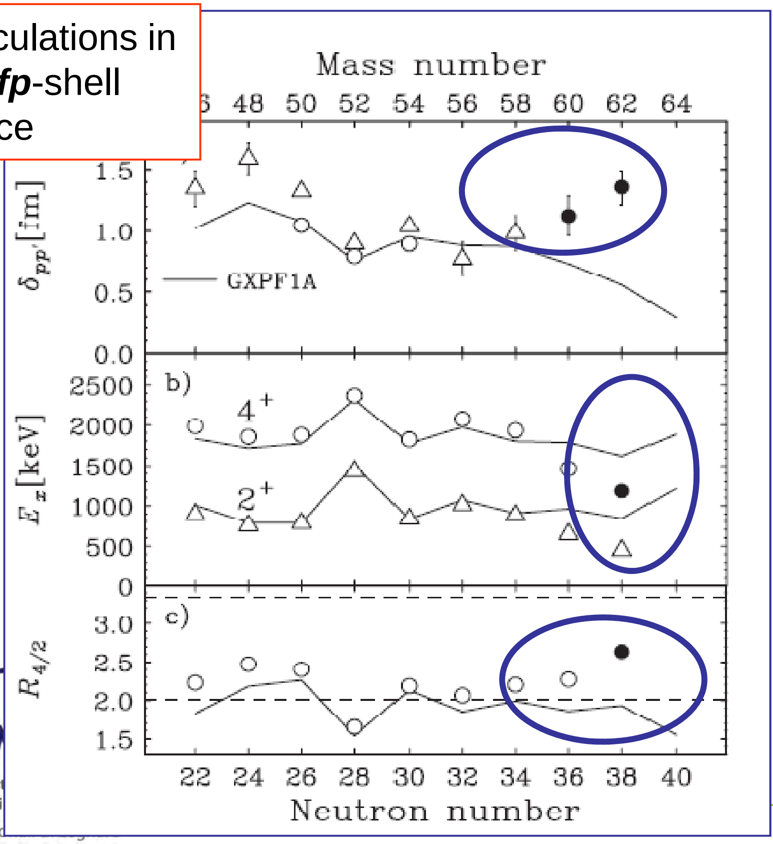

PRL 102, 012502 (2009) PHYSICAL REVIEW LETTERS week ending

Development of Large Deformation in ^{62}Cr

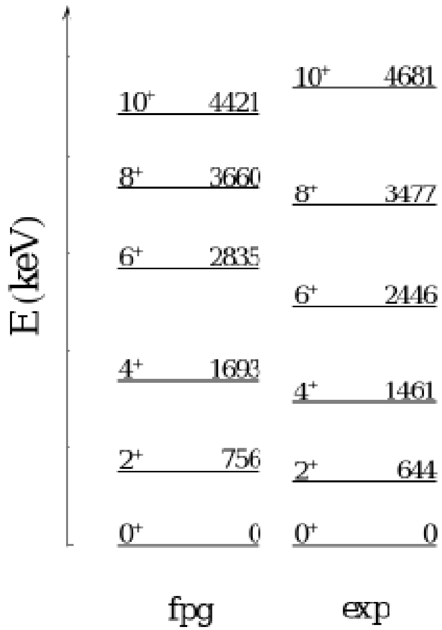
N. Aoi,[1] E. Takeshita,[1,2] H. Suzuki,[3] S. Takeuchi,[1] S. Ota,[4] H. Baba,[1] S. Bishop,[1] T. Fukui,[4] Y. Hashimoto,
E. Ideguchi,[7] K. Ieki,[2] N. Imai,[8] M. Ishihara,[1] H. Iwasaki,[6] S. Kanno,[2] Y. Kondo,[5] T. Kubo,[1] K. Kurita,[2] K
T. Minemura,[8] T. Motobayashi,[1] T. Nakabayashi,[5] T. Nakamura,[5] T. Nakao,[6] M. Niikura,[7] T. Okumura,[5] T.
H. Sakurai,[6] S. Shimoura,[7] R. Sugo,[2] D. Suzuki,[6] M. K. Suzuki,[6] M. Tamaki,[7] K. Tanaka,[1] Y. Togano,[2] and

^{64}Ni + ^{238}U at E_L = 400 MeV
at Prisma -Clara

Calculations in the ***fp***-shell space

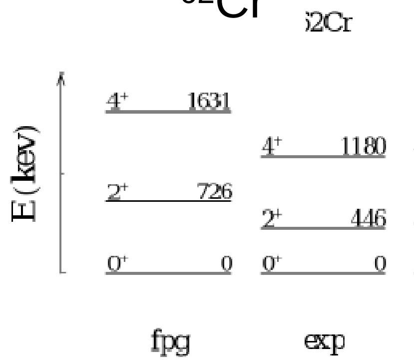


^{60}Cr

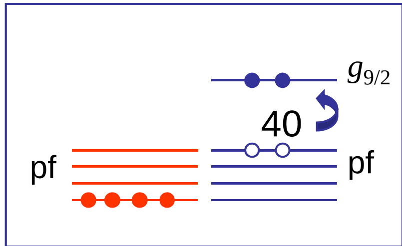


S.M.Lenzi et al.,
LNL Ann. Rep. 2008

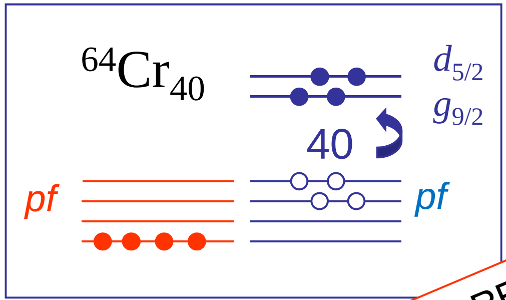
^{62}Cr

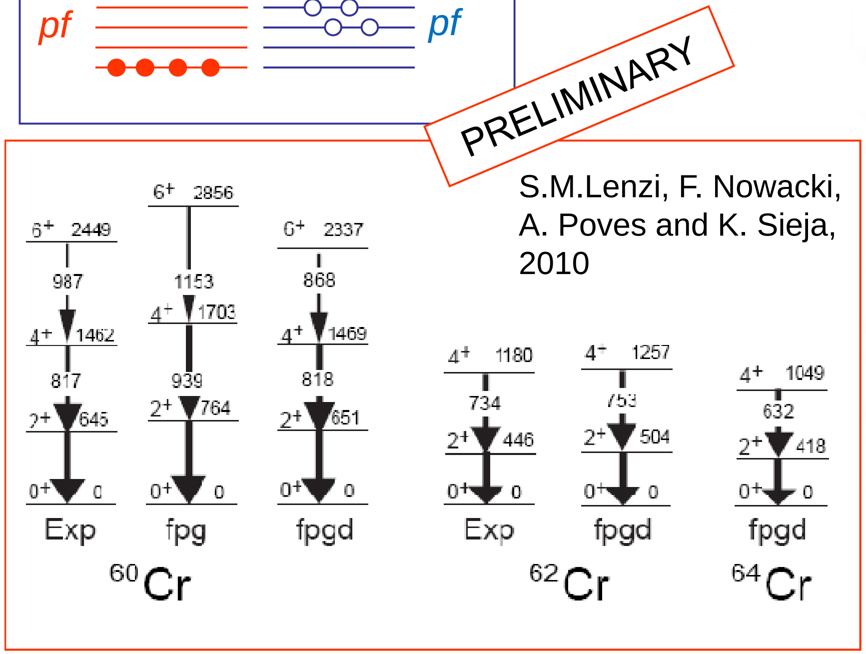


The experimental level schemes are also more collective than the calculated taken into account the **fpg** space

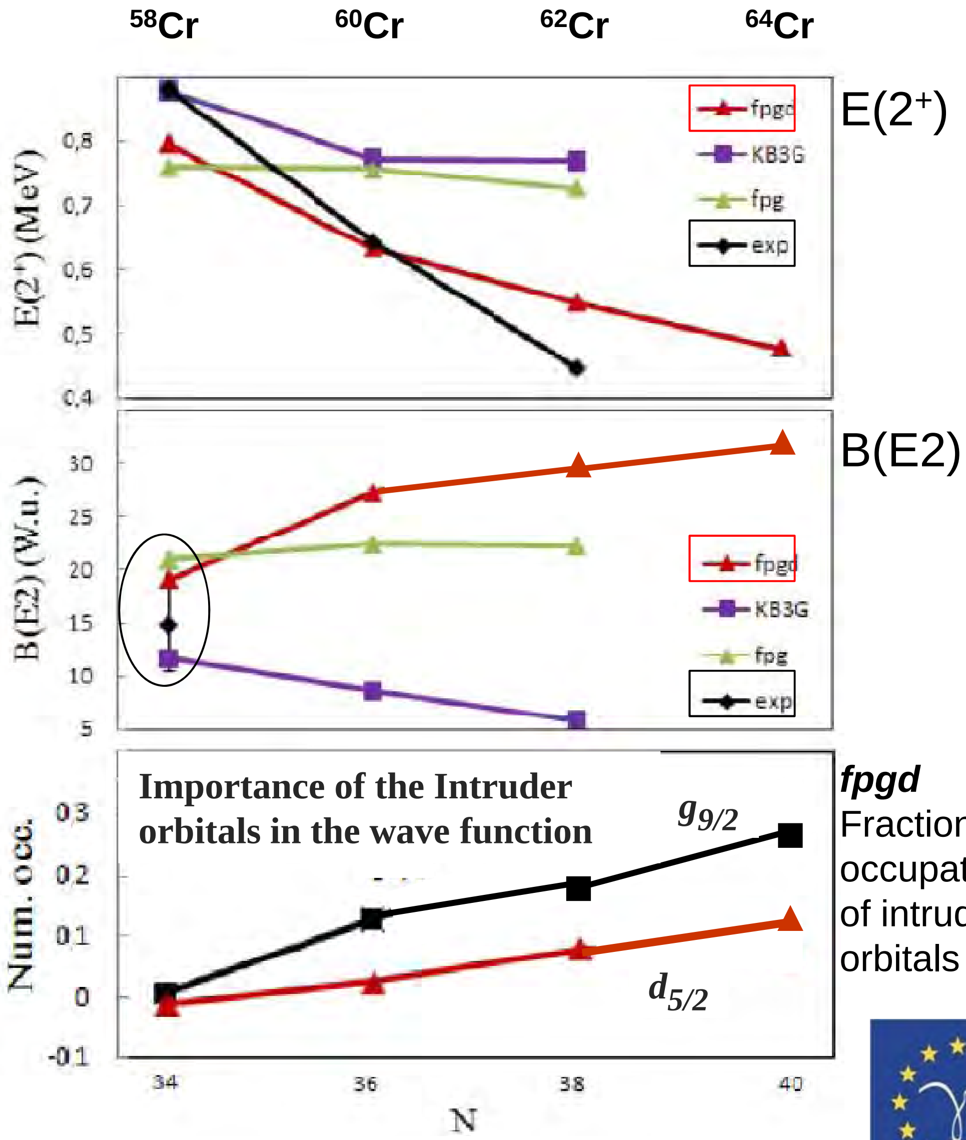


The **fpgd** interaction: Cr neutron-rich isotopes





S.M.Lenzi, F. Nowacki, A. Poves and K. Sieja, 2010



fpgd
Fractional occupation of intruder orbitals

Experimental B(E2) values are needed to test the model and eventually fix crucial matrix elements

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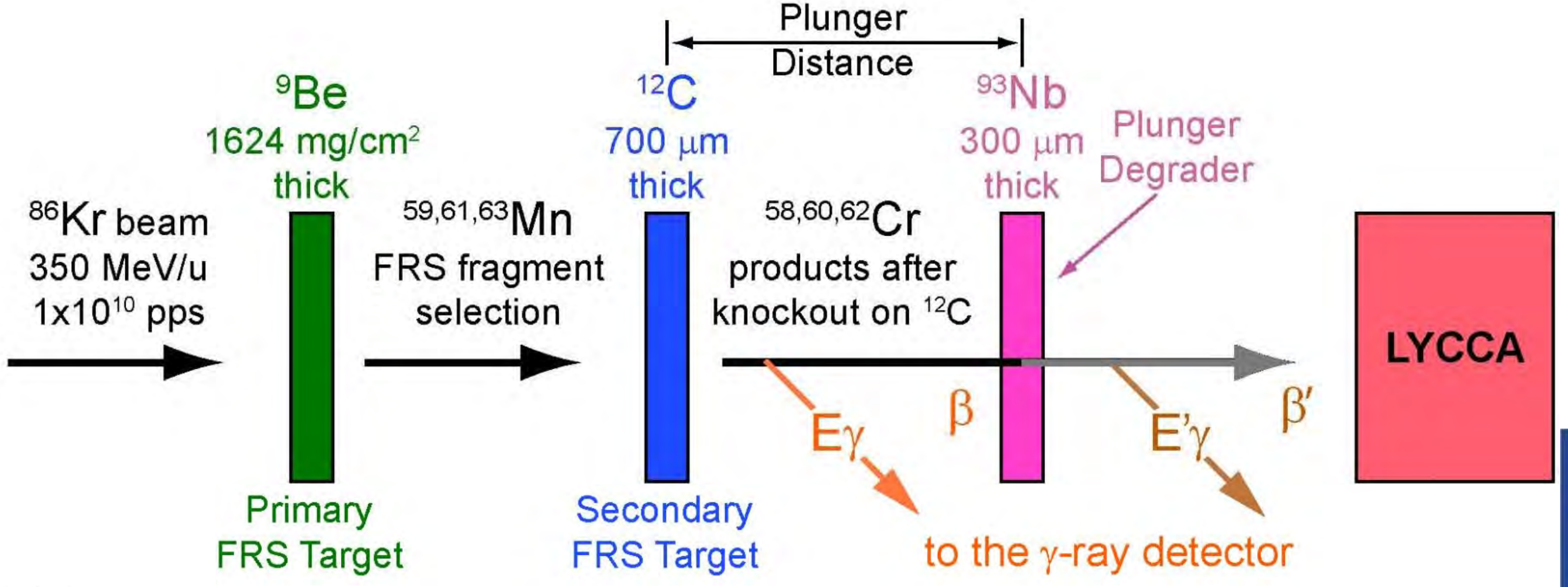
Proposal

The present proposed experiment aims at measuring the lifetimes of higher excited states of ^{58,60,62}Cr.

For ^{58}Cr the yrast states up to 8^+ and in particular the non yrast 2^+_2 state, to test the critical point character of this nucleus.

For ^{60,62}Cr the lifetimes of low spin states are fundamental for a more stringent test of the collective properties and the development of deformation in this region.

The predicted lifetimes are in the picosecond range and can be measured with the recoil differential distance method.



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Measuring deformation in the Third Island of Inversion

S.M.Lenzi, A. Dewald

and the

AGATA Collaboration

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Laboratori Nazionali di Legnaro

Outline of this presentation

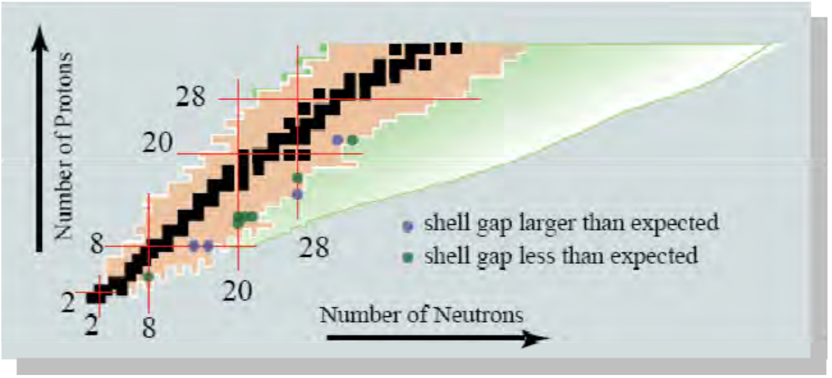
- The study of light and medium-light neutron-rich nuclei near major shell or sub-shell closures

- Previous experiments

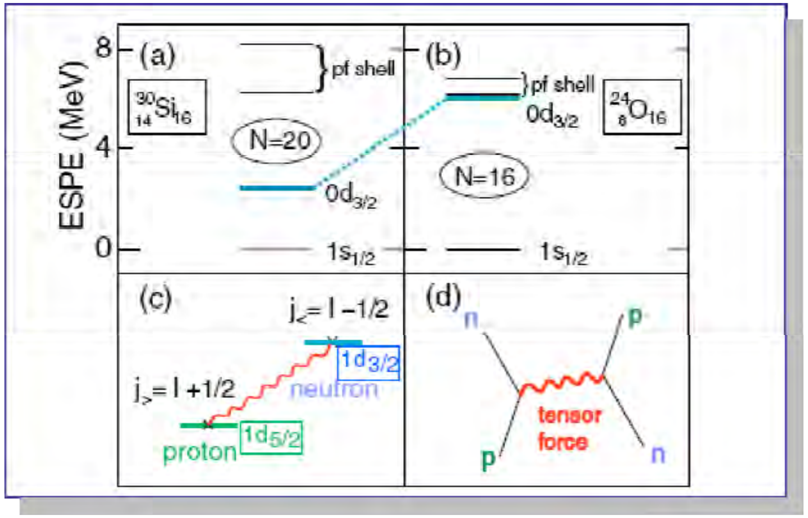
- The Proposal

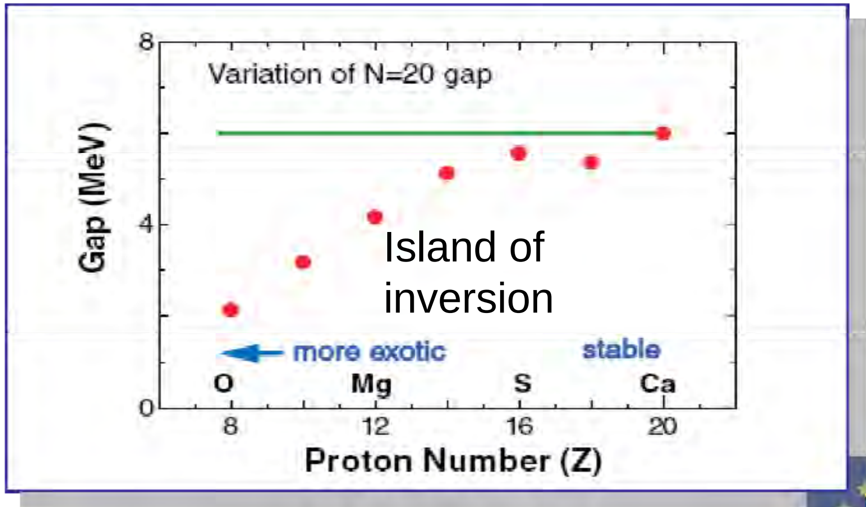
Shell evolution far from stability – The p-n spin-flip interaction

The neutron-rich side



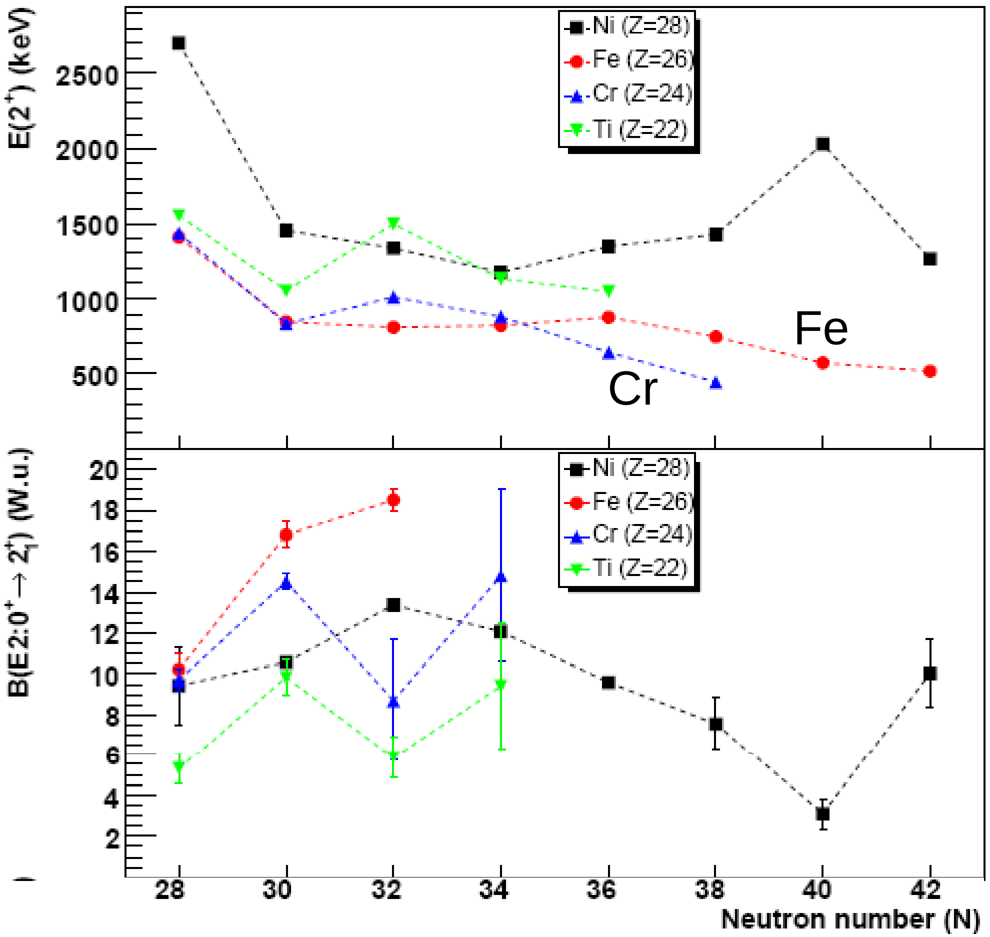
shell evolution along isotonic and isobaric chains





T. Otsuka EPJ S. Top. 156, 169 (2008)

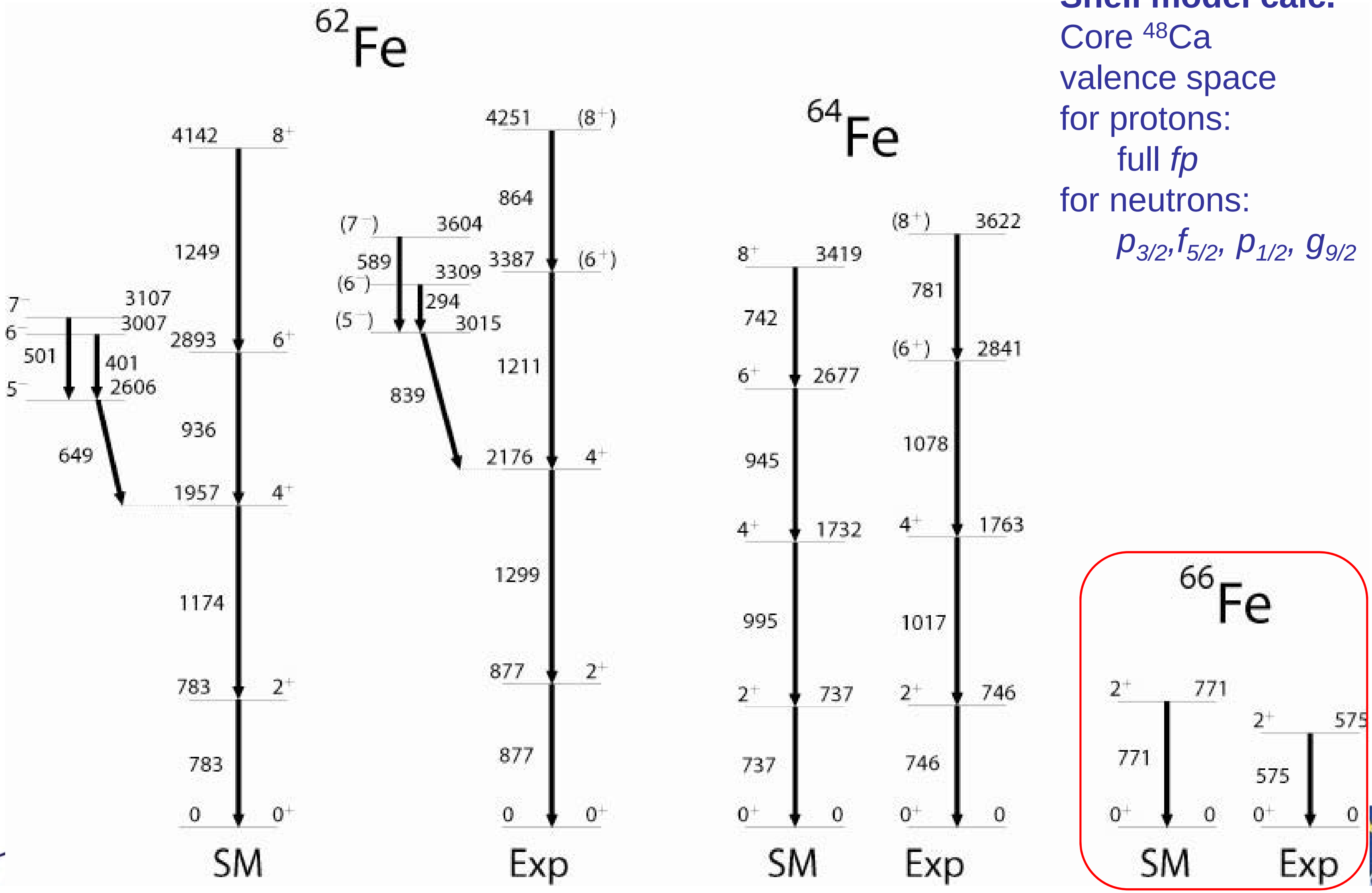
Removing protons from the $f_{7/2}$ shell



Experimental data only

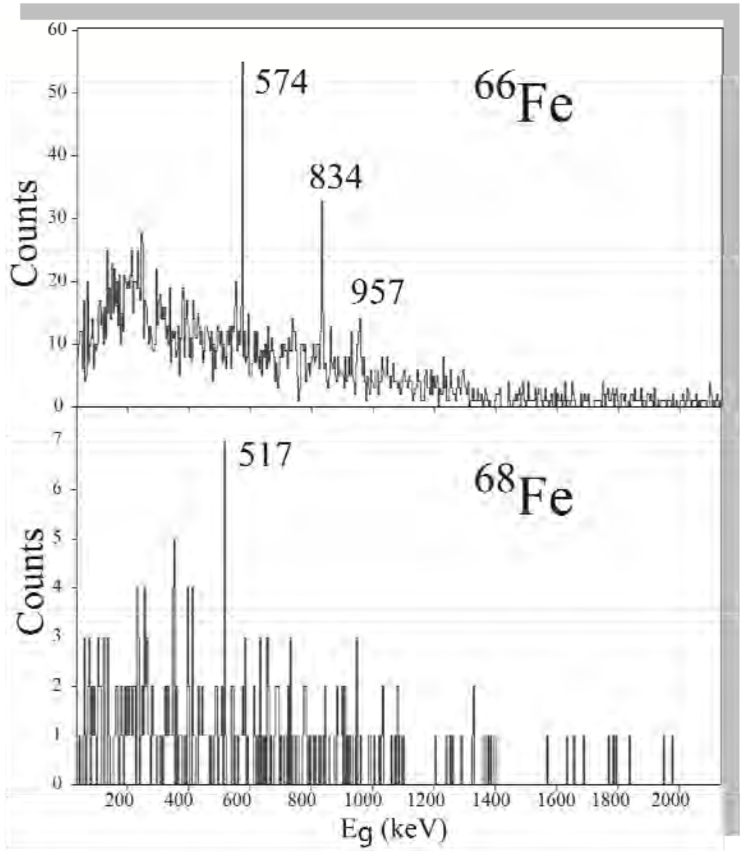
Even-even Fe isotopes

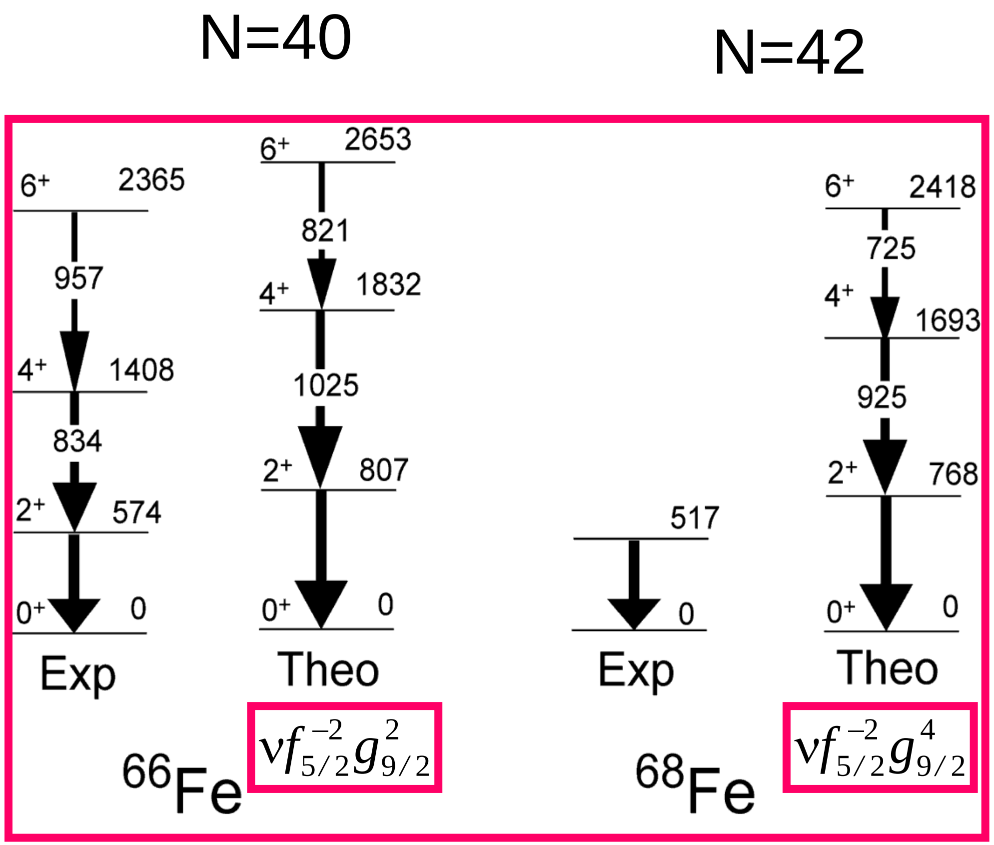
Shell model calc.
Core ^{48}Ca
valence space
for protons:
full *fp*
for neutrons:
$p_{3/2}, f_{5/2}, p_{1/2}, g_{9/2}$



Data on ^{64}Fe: (GANIL) O.Sorlin et al., NPA 660, 3 (1999) - (GAMMASPHERE) N.Hoteling et al., PRC74, 064313 (2006)
Data on ^{62}Fe: (GASP) T.Pawlat et al., Legnaro Annual Report 1995,7 - (GAMMASPHERE) A.N.Wilson et al., EPJ.A9,183 (2000)
(CLARA – PRISMA) S. Lunardi *et al.*, Phys. Rev. C **76**, 034303 (2007)

Beyond N=40: ^{66,68}Fe





SML et al.,
LNL Ann. Rep. 2008

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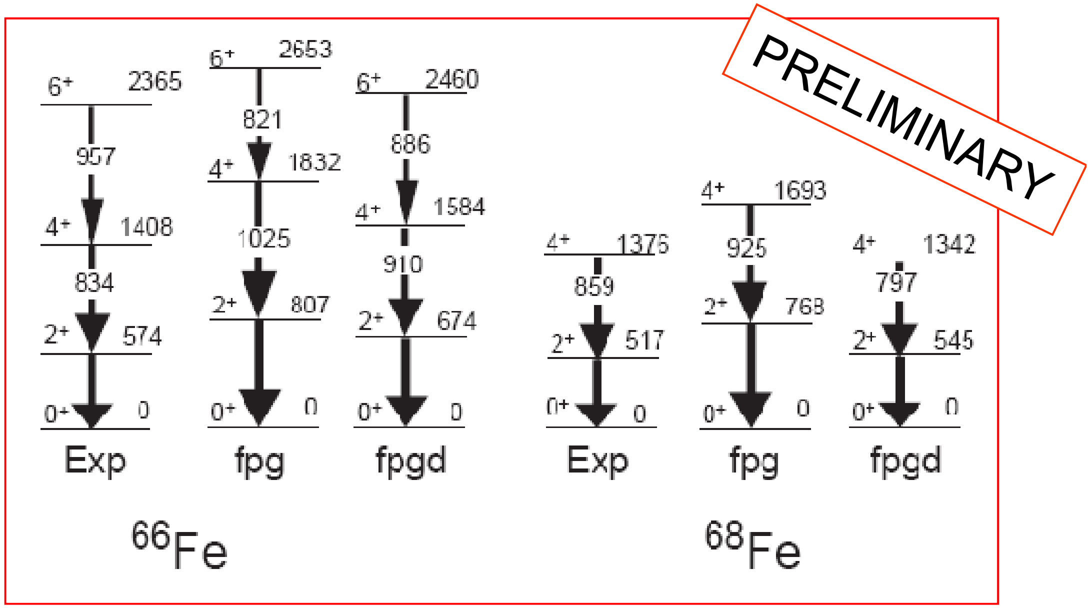
The new island of inversion

Lifetimes of the 2⁺ states in $^{62\text{-}66}Fe$ measured recently at GANIL (Ljungvall et al.) and MSU (Dewald et al.)

The SM calculations including the fpgd space describe also rather well these new lifetimes results.

From these calculations and the exp. E(2⁺), ^{68}Fe (N=42) is predicted to be still more collective than ^{66}Fe.



S. M. Lenzi, F. Nowacki , A. Poves, K. Sieja (2010)

Experimental lifetimes of the low lying states in ^{66}Fe (up to 6⁺) and ^{68}Fe (up to 4⁺) are needed to determine with better precision the matrix elements and characterize the deformation in this region.

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AGATA ADVANCED GAMMA TRACKING ARRAY

Lifetimes of low lying states in ^{66,68}Fe

Primary SIS beam	^{86}Kr	350 Mev/u , 1x10^{10} pps
Primary FRS target	^{9}Be	1624 mg/cm^2 thick

Secondary beam selected inflight on an event-by-event basis using

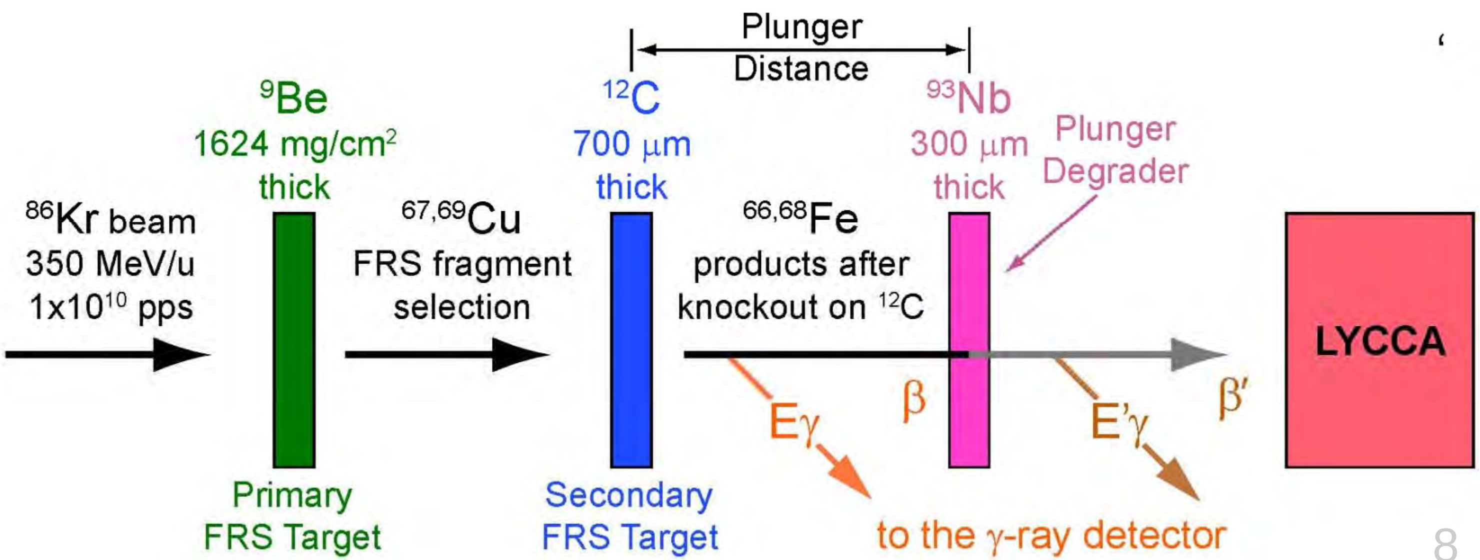
FRS standard settings	^{67,69}Cu	
Secondary FRS target	^{12}C	700 μm thick

^{66}Fe and ^{68}Fe will be populated in the proton knockout channel

Degrader for the plunger	^{93}Nb	300 μm thick

At least 3 different distances for each decay transition:

^{66}Fe: 2$^+$, 4$^+$ and 6$^+$ & ^{68}Fe: 2$^+$ and 4$^+$



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