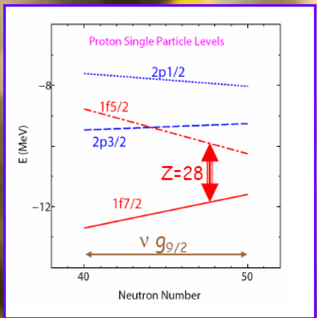
AGATA campaigns at GANIL and future plans

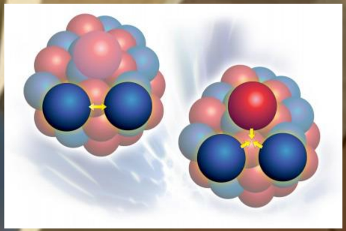
Colloque du GANIL 2017

E.Clément

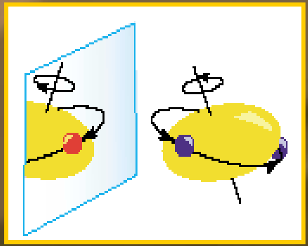
Shell evolution far from stability



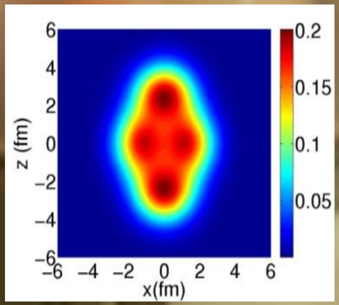
Three-body forces



Isospin symmetry breaking

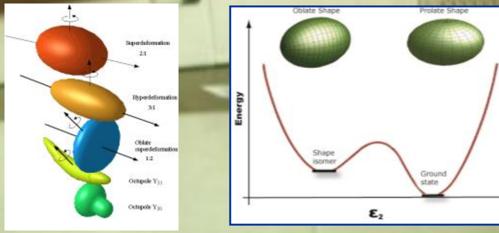


clusterization

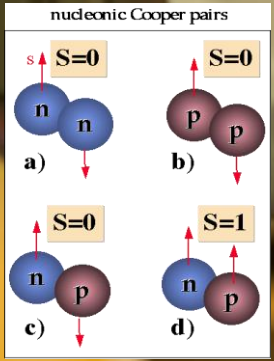


High-resolution gamma-ray spectroscopy is an optimum tool to study detailed nuclear structure properties and investigate how they emerge from fundamental interactions.

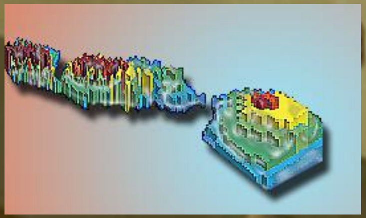
Nuclear shapes and coexistence



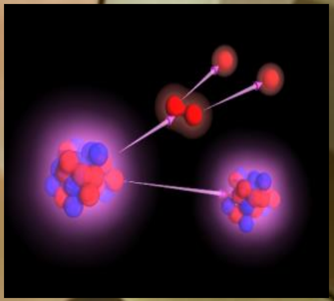
p-n pairing



Super heavy elements

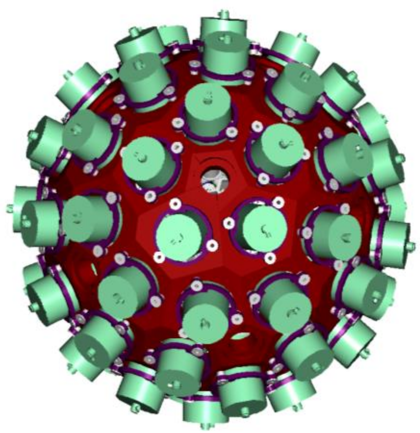


Nuclear Astrophysics

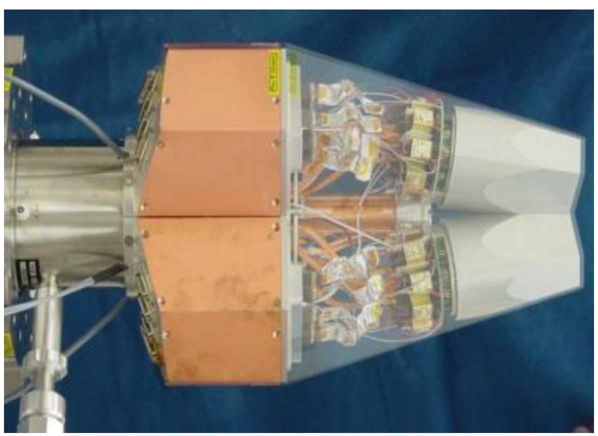


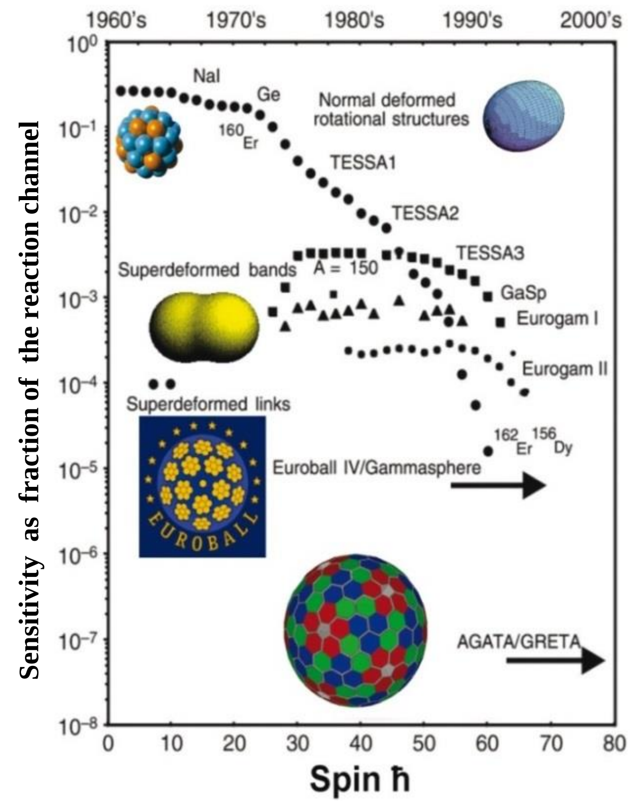
Coupling to the continuum

The AGATA project



- 180 (60 triple-clusters) 36-fold segmented crystals
- Amount of germanium: 362 kg
- Solid angle coverage: 82 %
- Singles rate >50 kHz
- Efficiency: 43% (M_γ=1) , 28% (M_γ=30)
- Peak/Total: 58% (M_γ=1), 49% (M_γ=30)
- Angular Resolution: ~1º



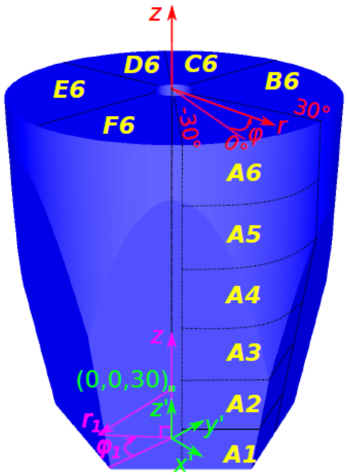


<u>Combination of:</u>

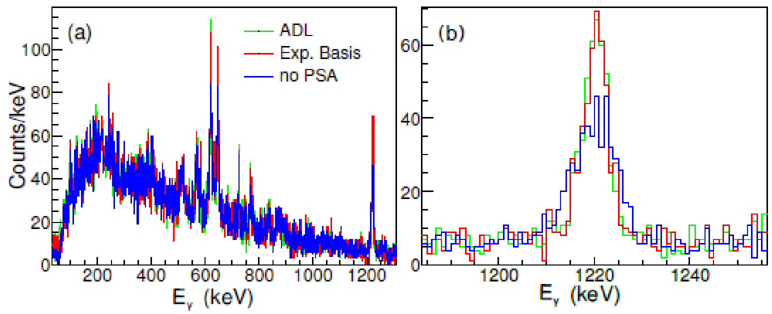
- ❑ segmented detector
- ❑ pulse-shape analysis
- ❑ tracking the γ rays
- ❑ digital electronics

The AGATA project

Improving the Pulse Shape Analysis using experimental basis. HJ. Li et al (GANIL)

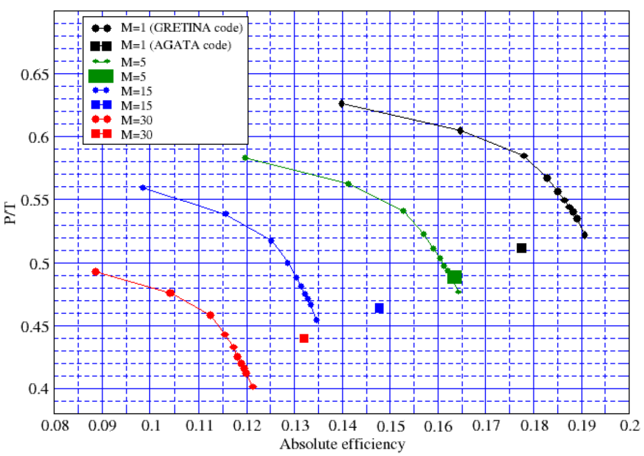


^{98}Zr data from e680



Case	FWHM	Area	
no PSA	9.7(21)	159(20)	
ADL	5.4(5)	147(15)	~60%
present	4.7(3)	157(16)	~20%

Improving the tracking in particular at low energy



High spins data from 2015 ^{158}Er data,
A. Korichi, A. Lopez (CSNSM) et al

Scanning tables in IPHC and Salamenca
Detectors technologies (IKP) **ENSAR2/JRA**
DAQ, FEBEE etc …

84 Technical papers related to AGATA and the developed technology

The AGATA project

✓The current AGATA MoU ends in 2020

✓The collaboration is preparing the second MoU for the construction of the 4π array following the recommendation of the NUPECC LRP

✓ AGATA has been identified as one of the key instrument for the next generation of heavy-ions accelerators

✓The collaboration has started the Technical Project Definition and a Physics White Book around the 5 possible Host Labs : GANIL/SPIRAL2, Univ. Jyvaskyla, HIE-ISOLDE, SPES and FAIR

→To be delivered by end of 2018

The AGATA project

19 PRC, 4 Letters and 1 EPJA since 2012

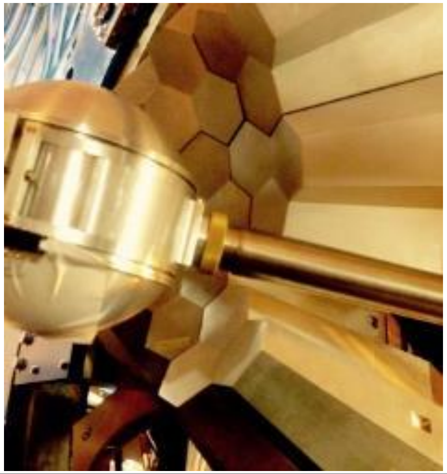
LNL
Coupled to the magnetic spectrometer PRISMA

1 PRC, 1 Letter since 2016

GSI
Fast radioactive beams coupled to Lycca

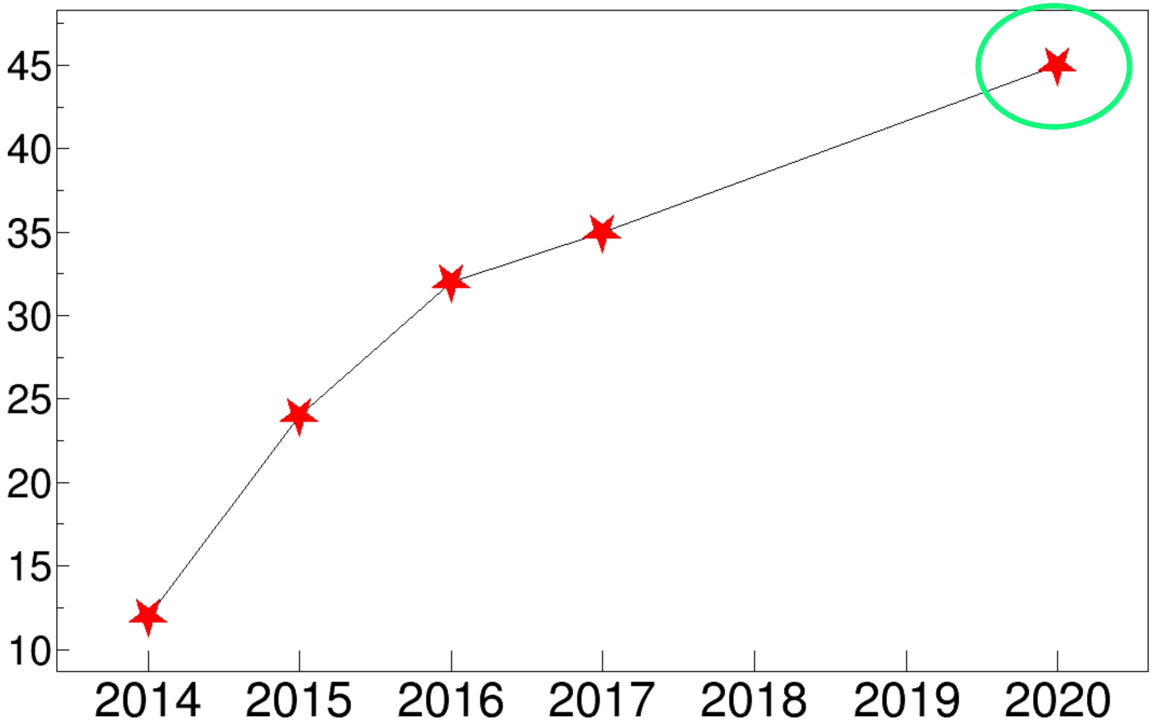
1 PRC, 1 Letter since 2017

GANIL
Coupled to VAMOS, NEDA/N-Wall, VAMOS g.f.m., MUGAST

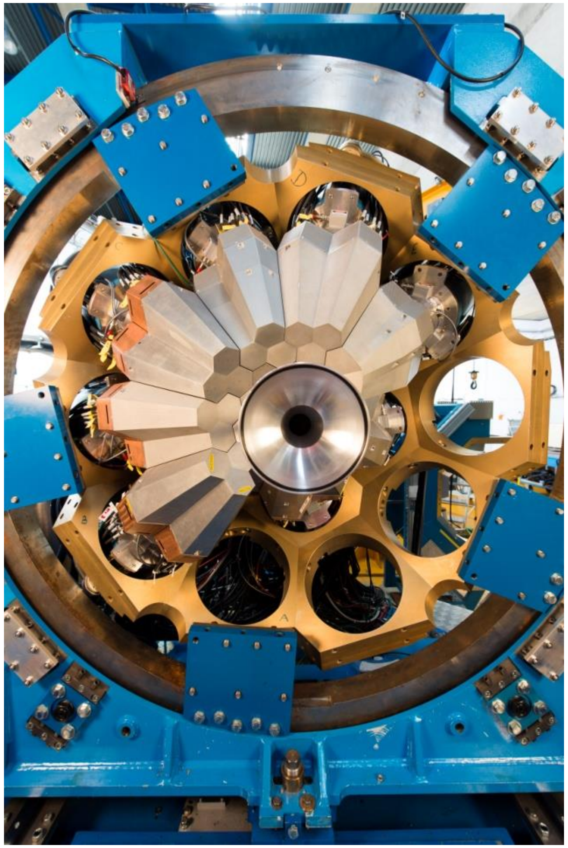


LNL 2010-2011 → **GSI 2012-2014** → **GANIL 2015-2019 (2020)**

The AGATA project



S. Akkoyun, et al, NIMA 669, 26-58 (2012)



The GANIL Campaign

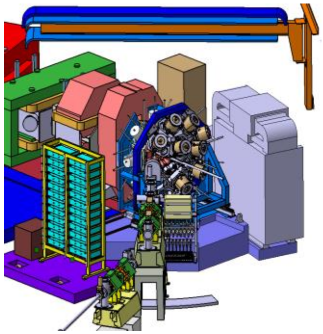
GANIL beams

High intensity stable beams up to ^{238}U

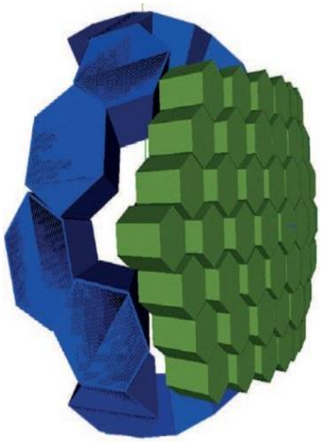
- Multi-nucleon transfer
- Fusion-fission
- Fusion-evaporation

Radioactive SPIRAL1 beams

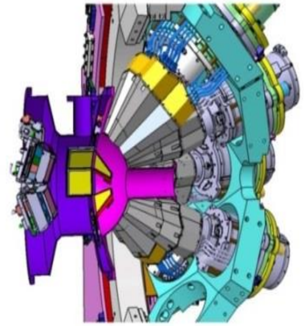
- Coulomb excitation
- Transfer reactions



VAMOS

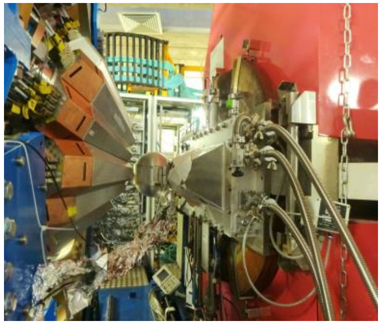


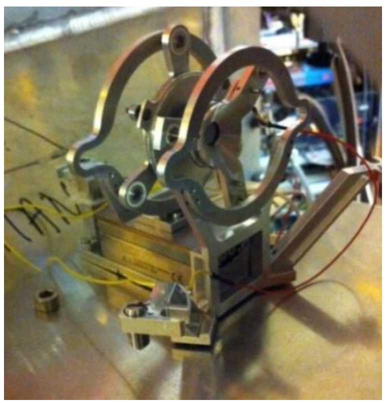
NEDA



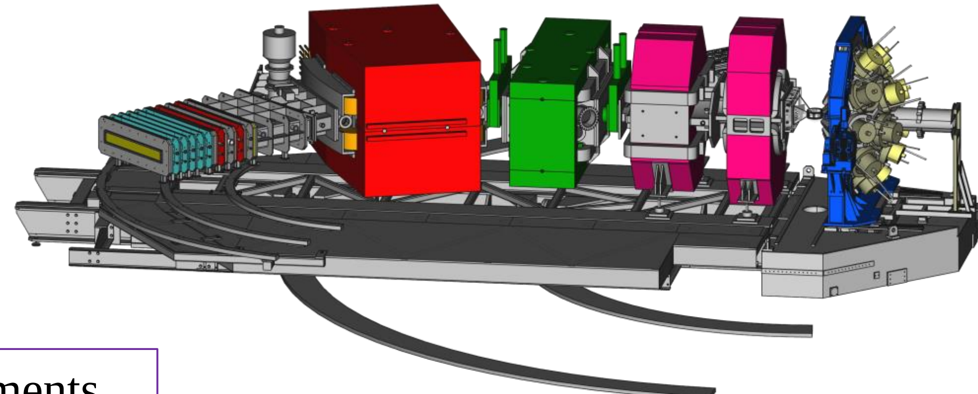
MUGAST

The GANIL Campaign



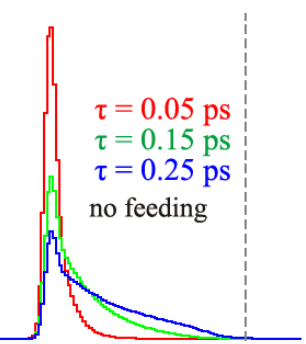


35 detectors on-line : Single efficiency measured at 3.4(1)% in nominal position at 1.408 MeV (GEANT4 = 3.6%)

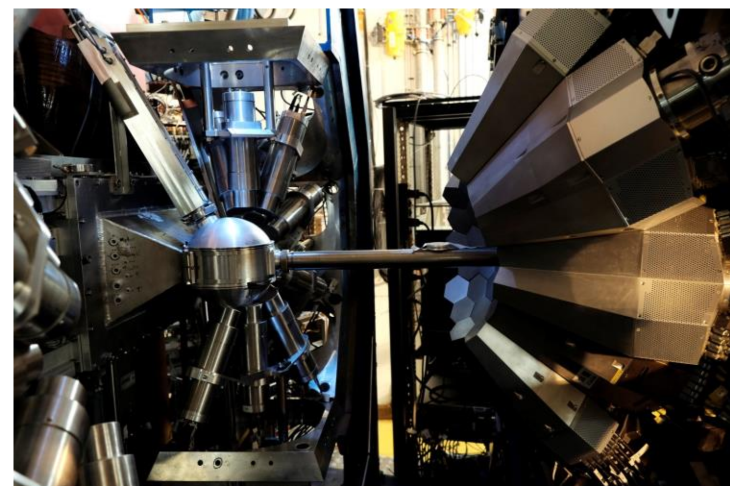


Lifetime measurements

2015-2017: 93% of performed experiments are lifetime measurements from fs to μs



E. Clément et al, NIMA 855, 1-12 (2017)
M. Vandebrouck et al, NIMA 812, 112-117 (2016)
Y. H. Kim et al, Eur.Phys.J. A 53, 162 (2017)



FATIMA-PARIS detectors coupled to AGATA

The GANIL Campaign organization

The AGATA campaign at GANIL has been extend to end of 2019

Each GANIL PAC has a "PrePac" workshop with a specific call : ***AGATA Collaboration Meeting***

- 1st PAC in 2014 : VAMOS (10 experiments approved)
- 2nd PAC in 2015 : VAMOS || NEDA (10 experiments approved)
- 3rd PAC in 2016 : NEDA (6 experiments approved)
- 4th PAC November 2017. The GANIL management has decided to fully open the call
- 5th PAC will be organized in the middle of 2018

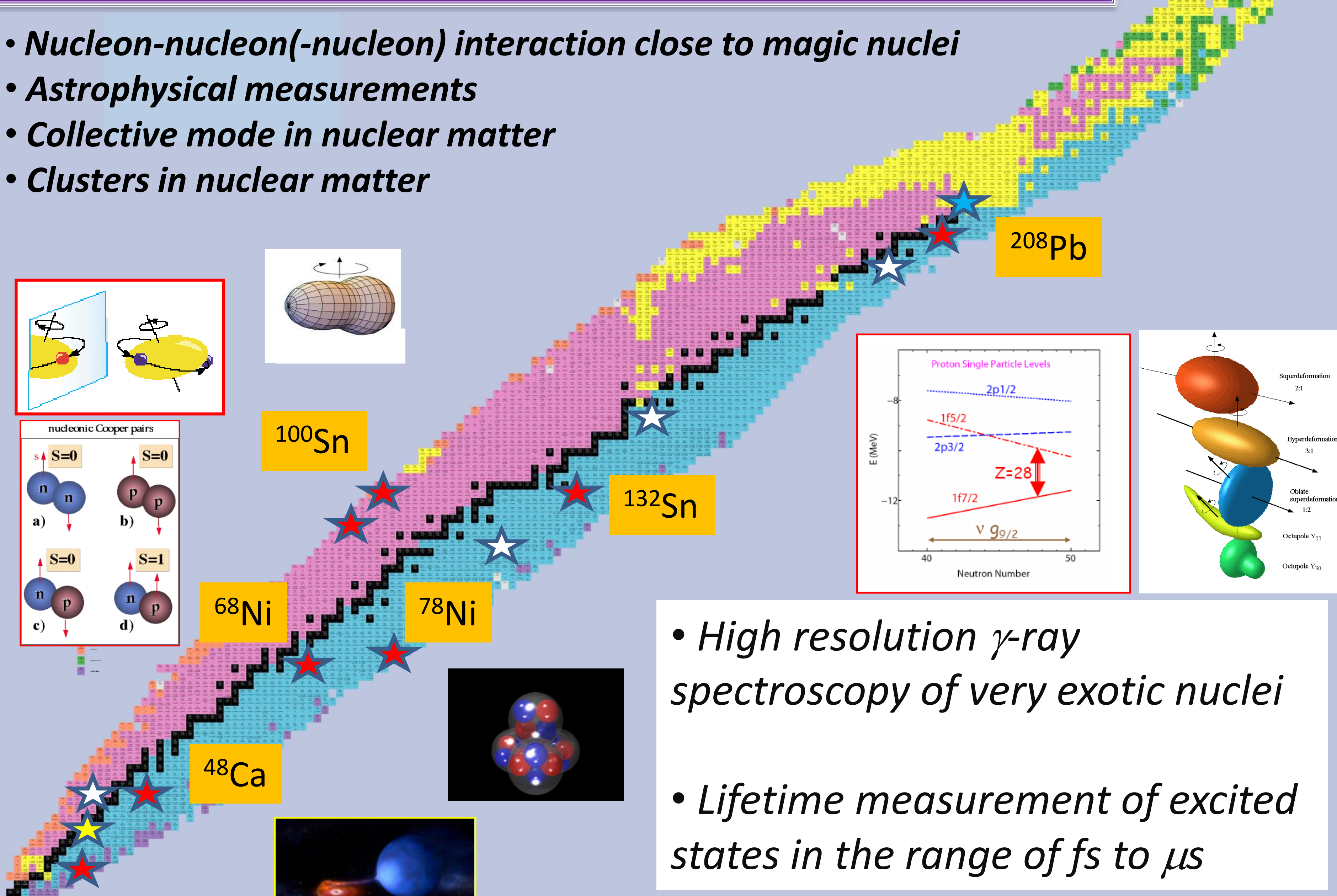
The next PrePac meeting of the collaboration will be organized on the 7th -9th of February

708 UT have been already approved
447 UT have been performed over 15 experiments producing 626 To of data on GRID

1st Analysis workshop organized in GANIL last 17th -21st of October 2016.
The second workshop is organized on the 16th -18th January 2018

The physics of AGATA@GANIL is the in-beam high resolution γ-ray spectroscopy of exotic nuclei populated by heavy-ions collisions

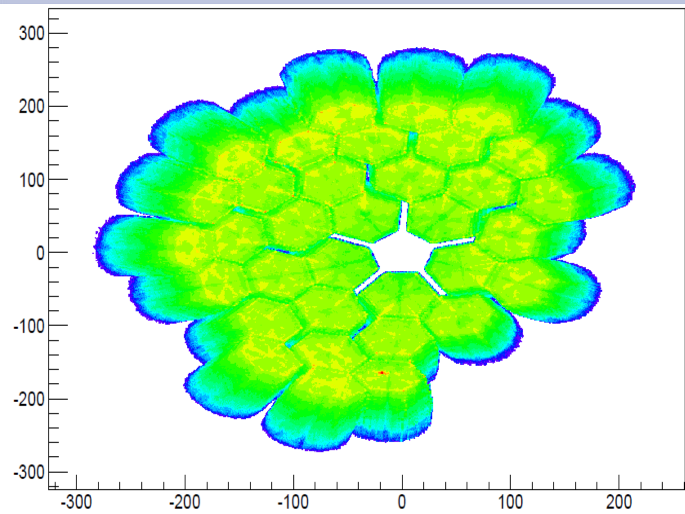
- ***Nucleon-nucleon(-nucleon) interaction close to magic nuclei***
- ***Astrophysical measurements***
- ***Collective mode in nuclear matter***
- ***Clusters in nuclear matter***

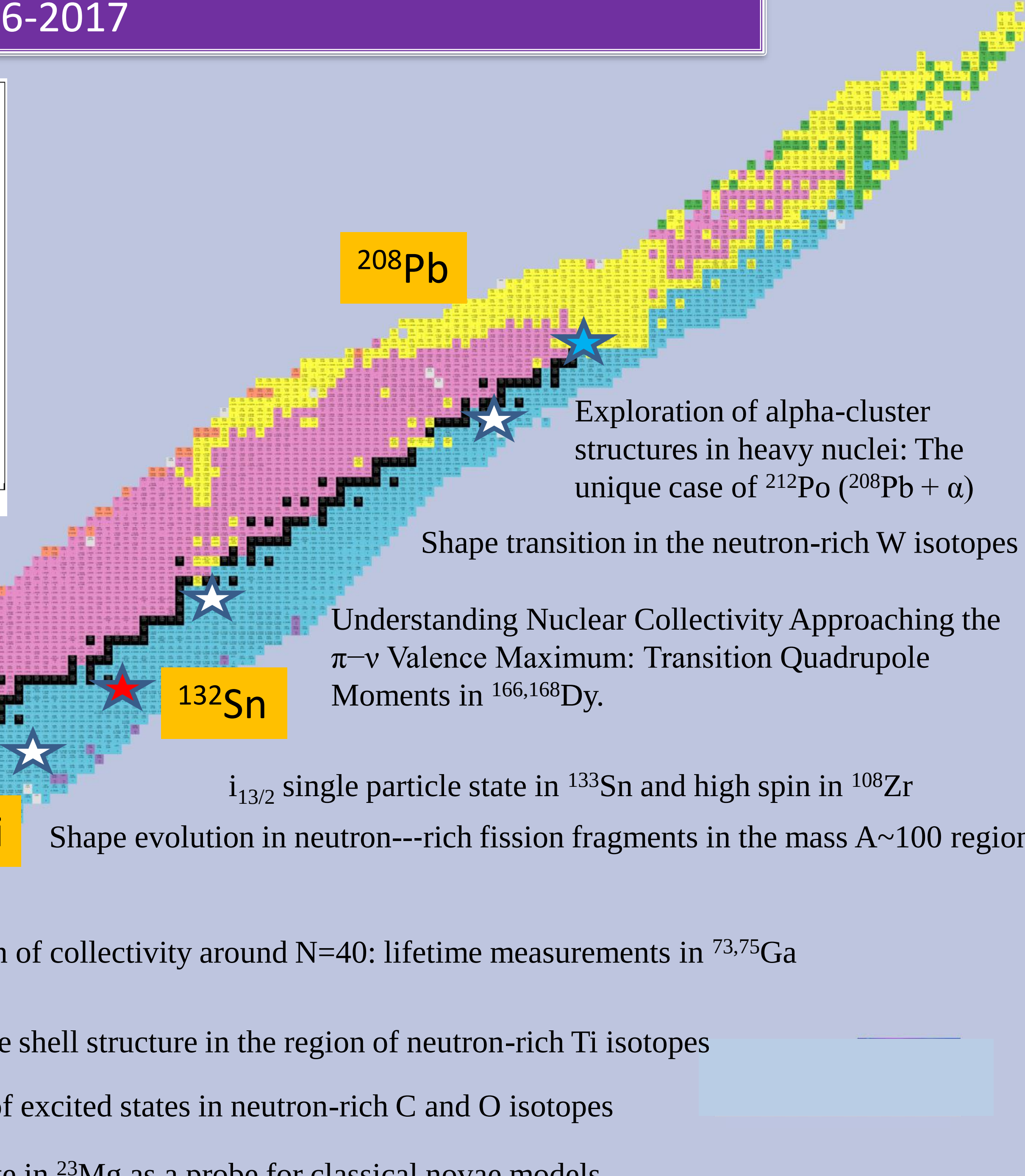


- *High resolution γ-ray spectroscopy of very exotic nuclei*

- *Lifetime measurement of excited states in the range of fs to μs*

Experiments performed in 2016-2017





Exploration of alpha-cluster structures in heavy nuclei: The unique case of ^{212}Po (^{208}Pb + α)

Shape transition in the neutron-rich W isotopes

Understanding Nuclear Collectivity Approaching the π−ν Valence Maximum: Transition Quadrupole Moments in ^{166,168}Dy.

$i_{13/2}$ single particle state in ^{133}Sn and high spin in ^{108}Zr

Shape evolution in neutron---rich fission fragments in the mass A~100 region

Evolution of collectivity around N=40: lifetime measurements in ^{73,75}Ga

Evolution of the shell structure in the region of neutron-rich Ti isotopes

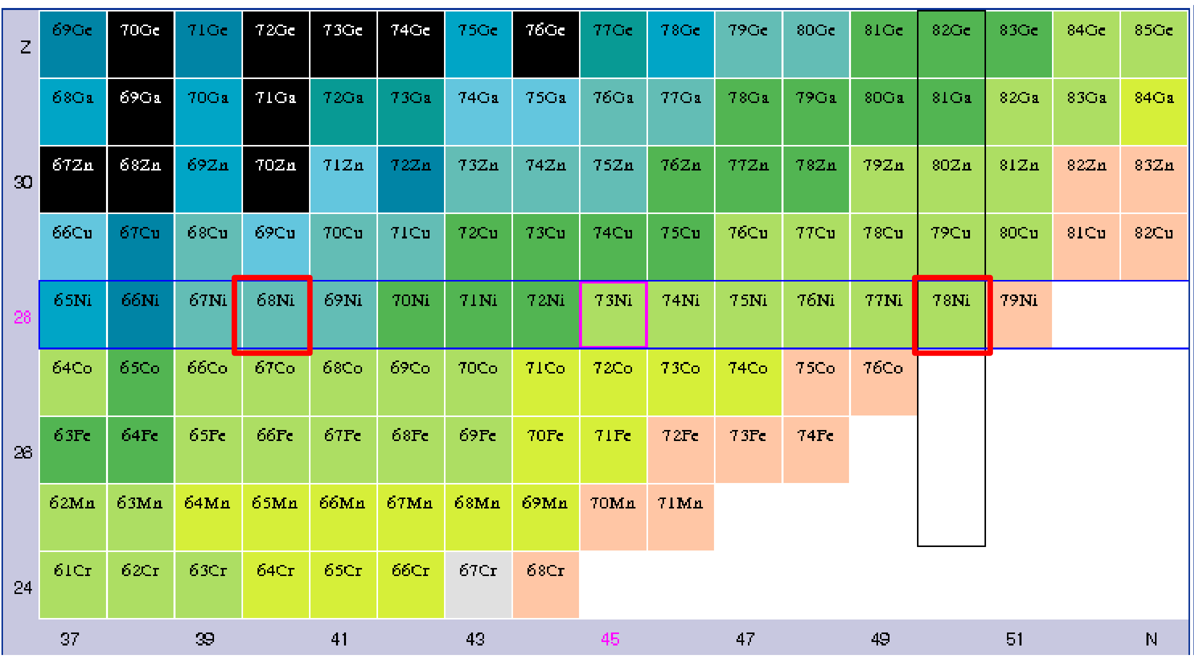
Lifetime measurements of excited states in neutron-rich C and O isotopes

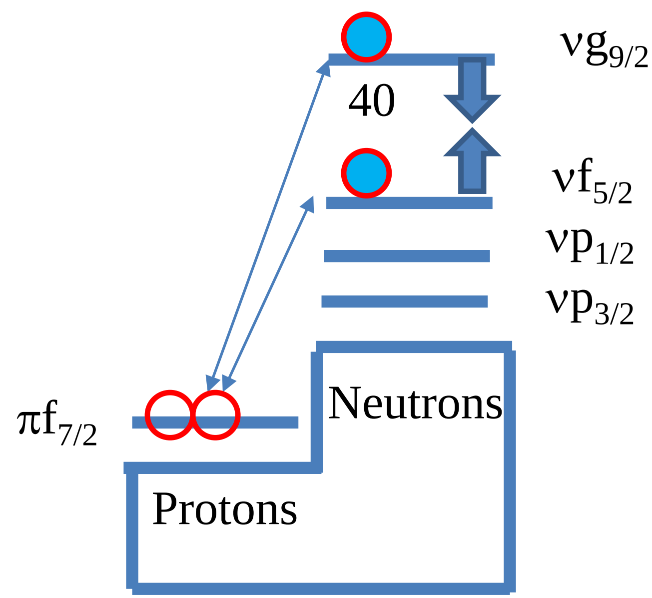
The lifetime of the 7.786 MeV state in ^{23}Mg as a probe for classical novae models

Shell evolution around Z=28

Interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe

- Characterizing the islands of inversion, formed near the magic numbers.
- These are new regions of deformation with configuration involving intruder orbitals from the above main shell.
- While a signature of deformation is given by the energy of the first excited states, their lifetimes allows a better understanding of their properties by comparison with LSSMC



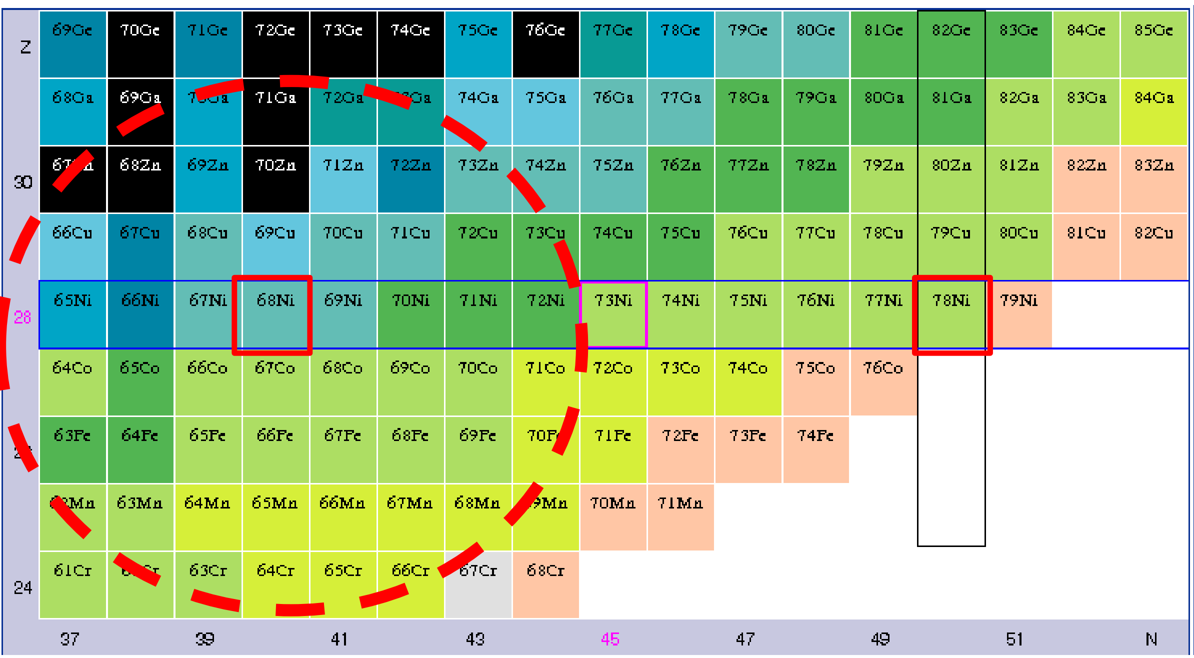


LPNS interaction

Shell evolution around Z=28

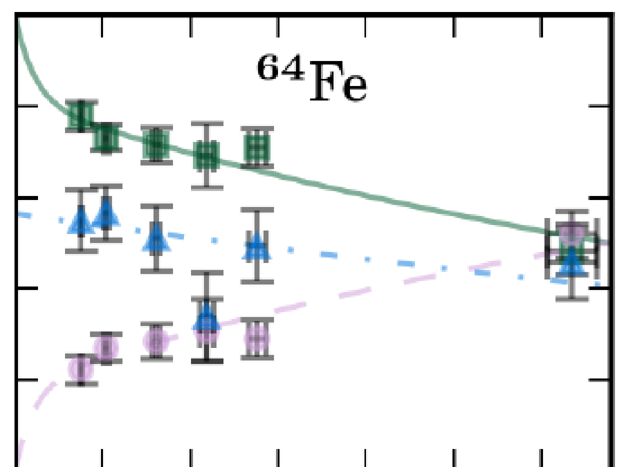
laboratoire commun CEA/DSM CNRS/IN2P3

interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe



Measurement of lifetimes in $^{62;64}$Fe, $^{61;63}$Co and ^{59}Mn

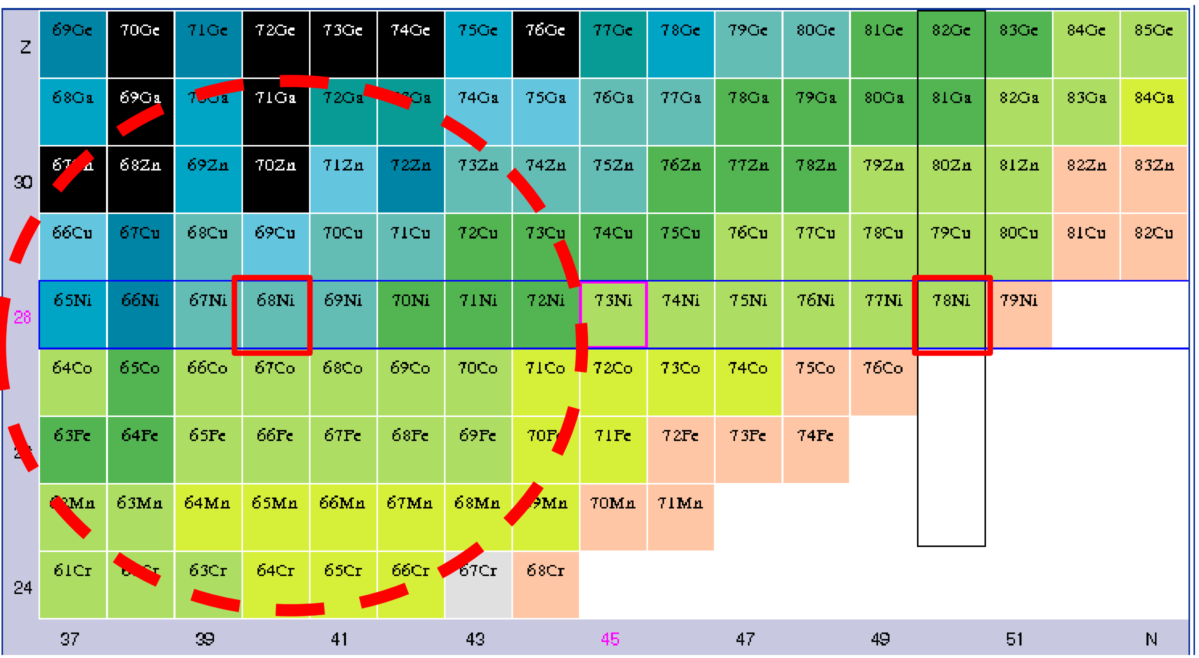
2015 Data.
Lifetimes of the 4^{+} states in $^{62;64}$Fe and the 11/2^{-} in $^{61;63}$Co and ^{59}Mn



M. Klintefjord et al., PRC 95, 024312 (2017)

Shell evolution around Z=28

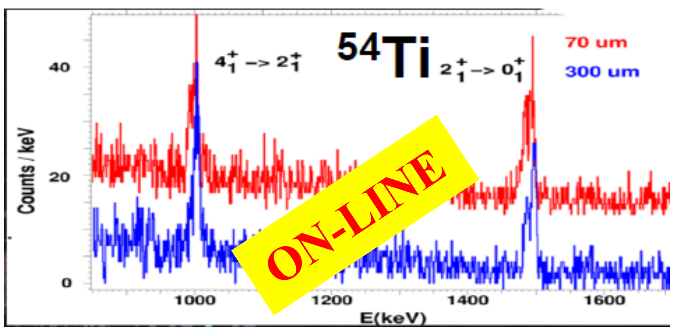
interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe



Lifetimes in ^{56}Ti and ^{55}V

2016 Data

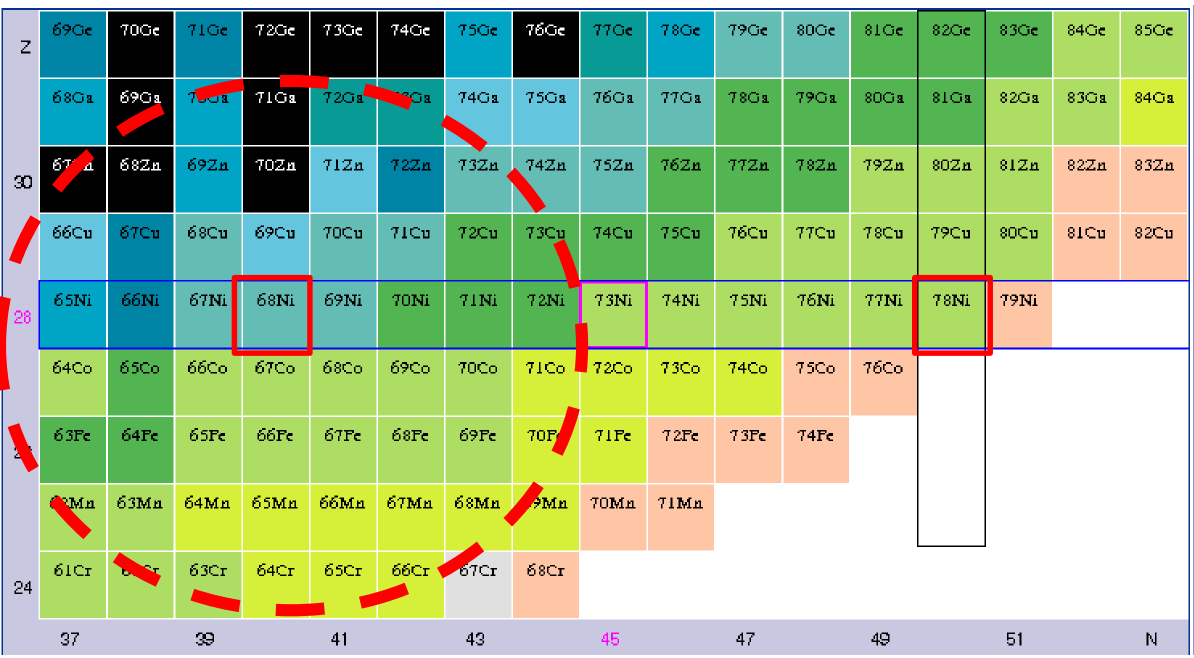
Shape evolution: subshell closures and development of deformation



Ch. Fransen et al.

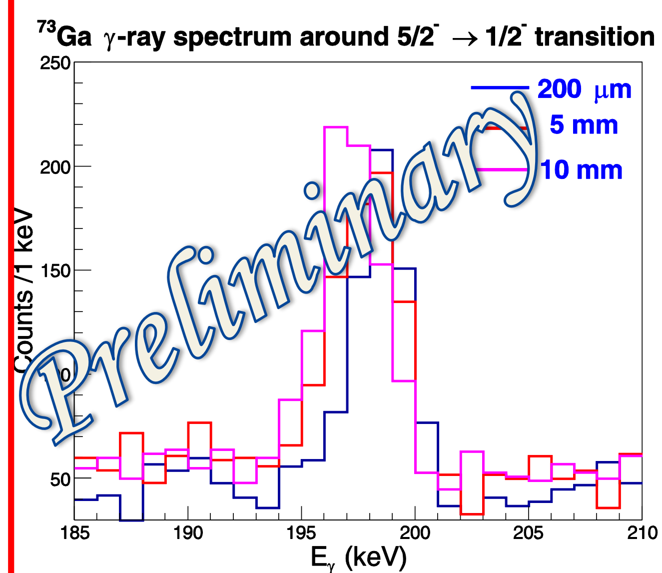
Shell evolution around Z=28

interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe



Lifetime of the 5/2$^-$ state in Ga decaying to a "degenerate" g.s

2016 Data



I. Celikovic, C. Michelagnoli et al.

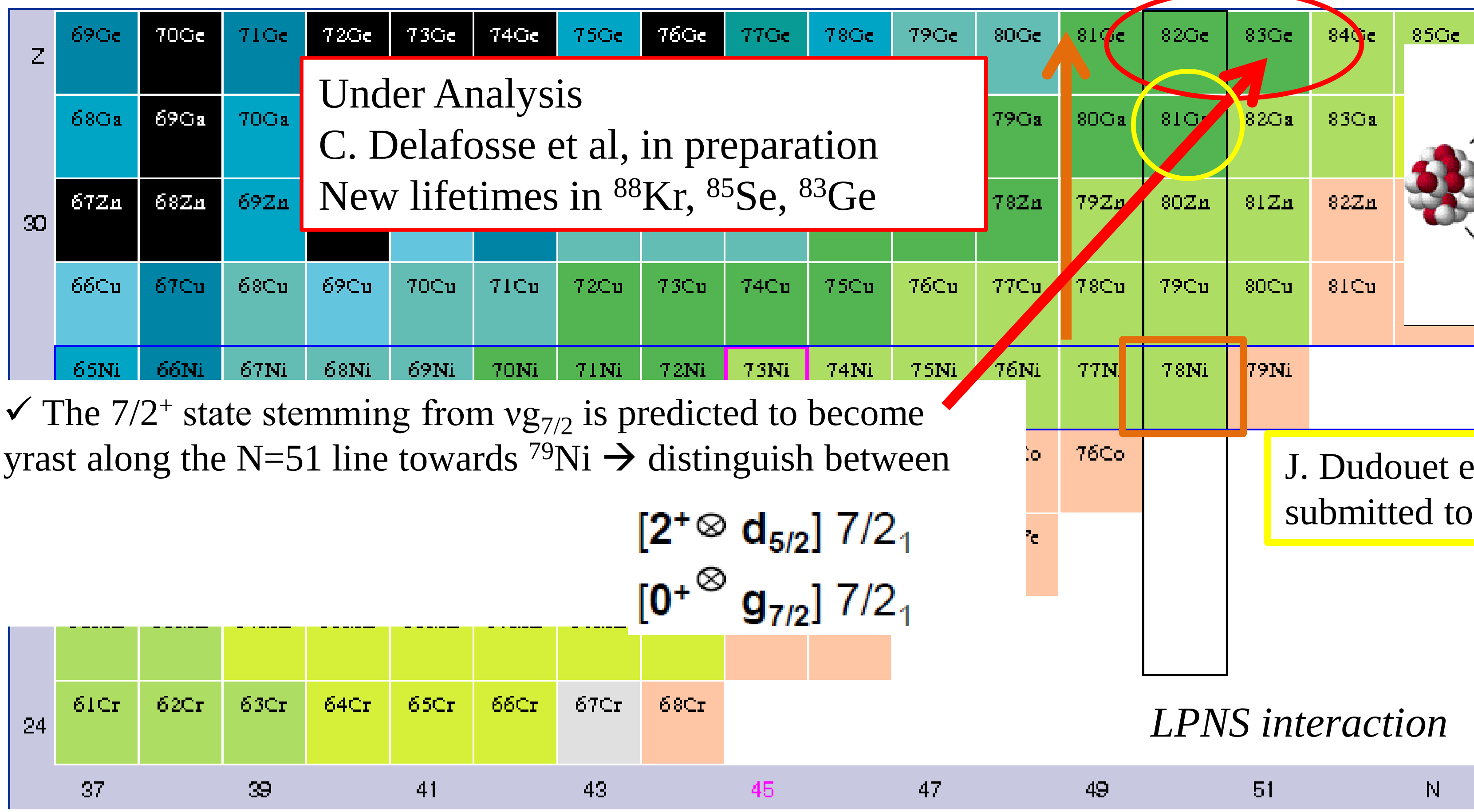
Shell evolution around Z=28

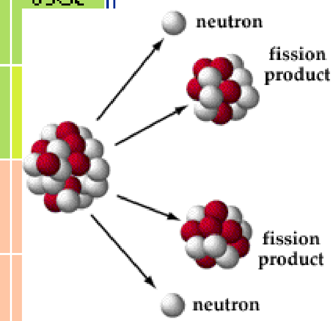
Understanding the single-particle evolution above N = 50 towards ^{78}Ni

J. Dudouet et al, PRL 118, 162501 (2017)

^{96}Kr

Shape transition at N=60





Under Analysis
C. Delafosse et al, in preparation
New lifetimes in ^{88}Kr, ^{85}Se, ^{83}Ge

✓ The 7/2$^+$ state stemming from $\nu g_{7/2}$ is predicted to become yrast along the N=51 line towards ^{79}Ni → distinguish between

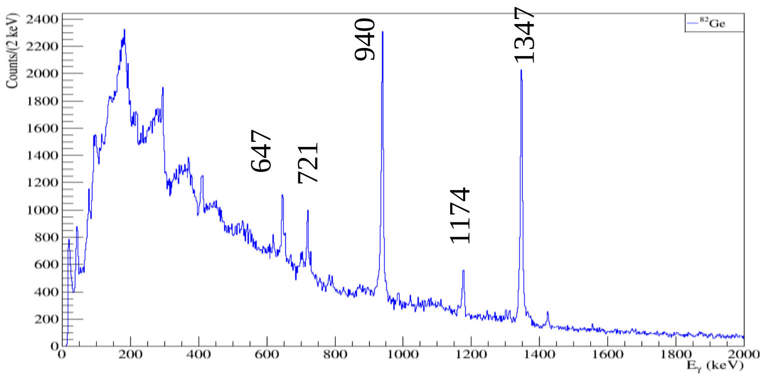
$$[2^+ \otimes d_{5/2}]\ 7/2_1$$

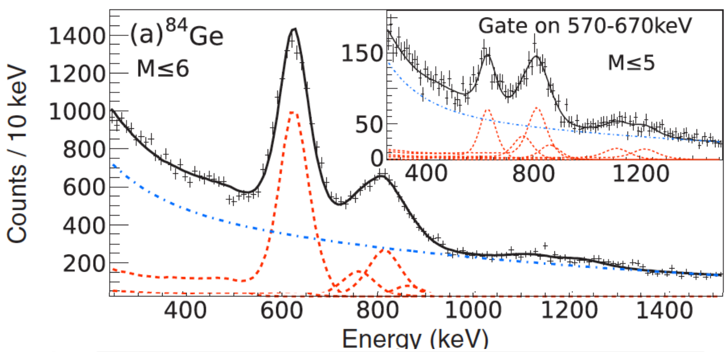
$$[0^+ \otimes g_{7/2}]\ 7/2_1$$

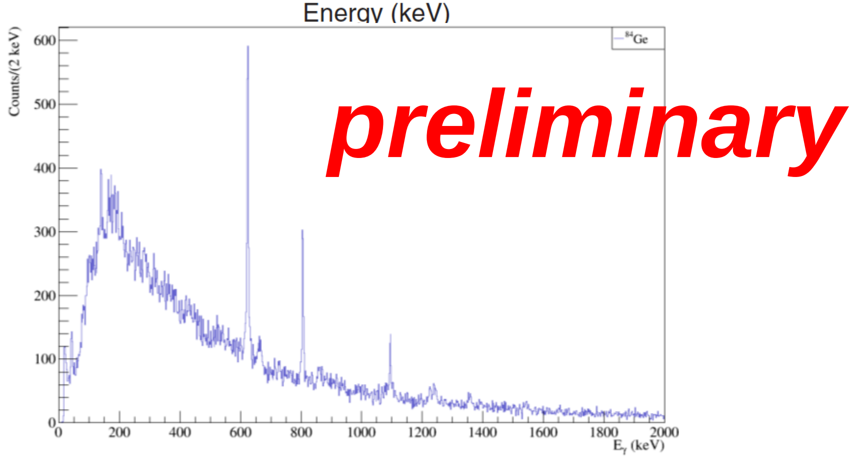
J. Dudouet et al., to be submitted to PRL

LPNS interaction

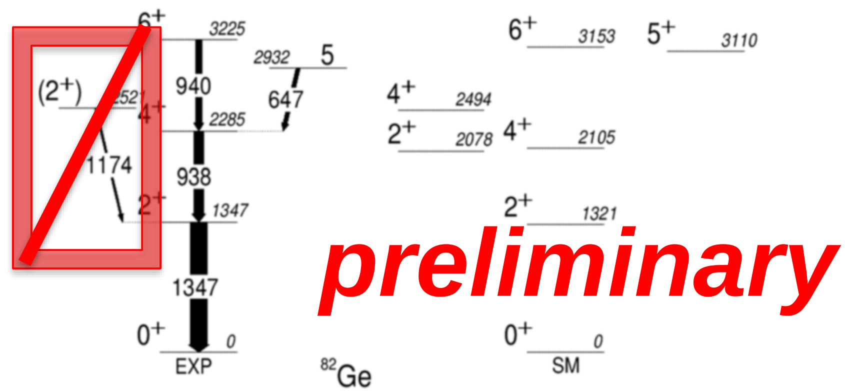
Shell evolution around Z=28



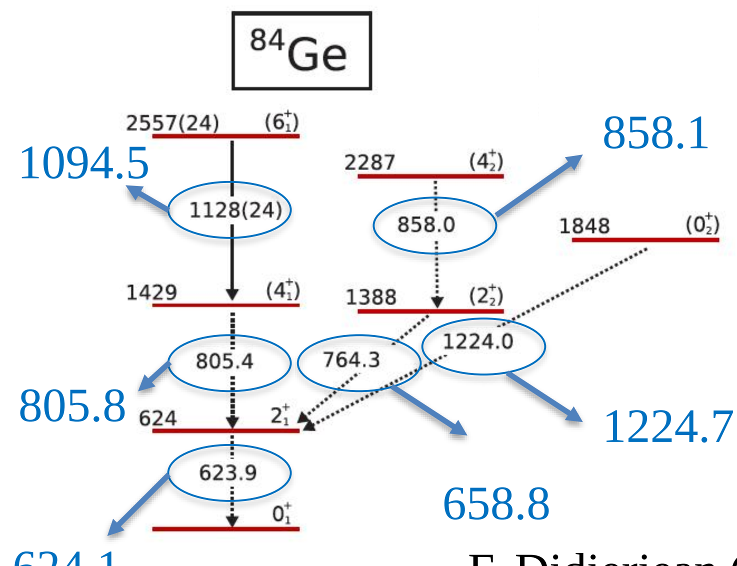




E. Sahin et al. / Nuclear Physics A 893 (2012) 1–12



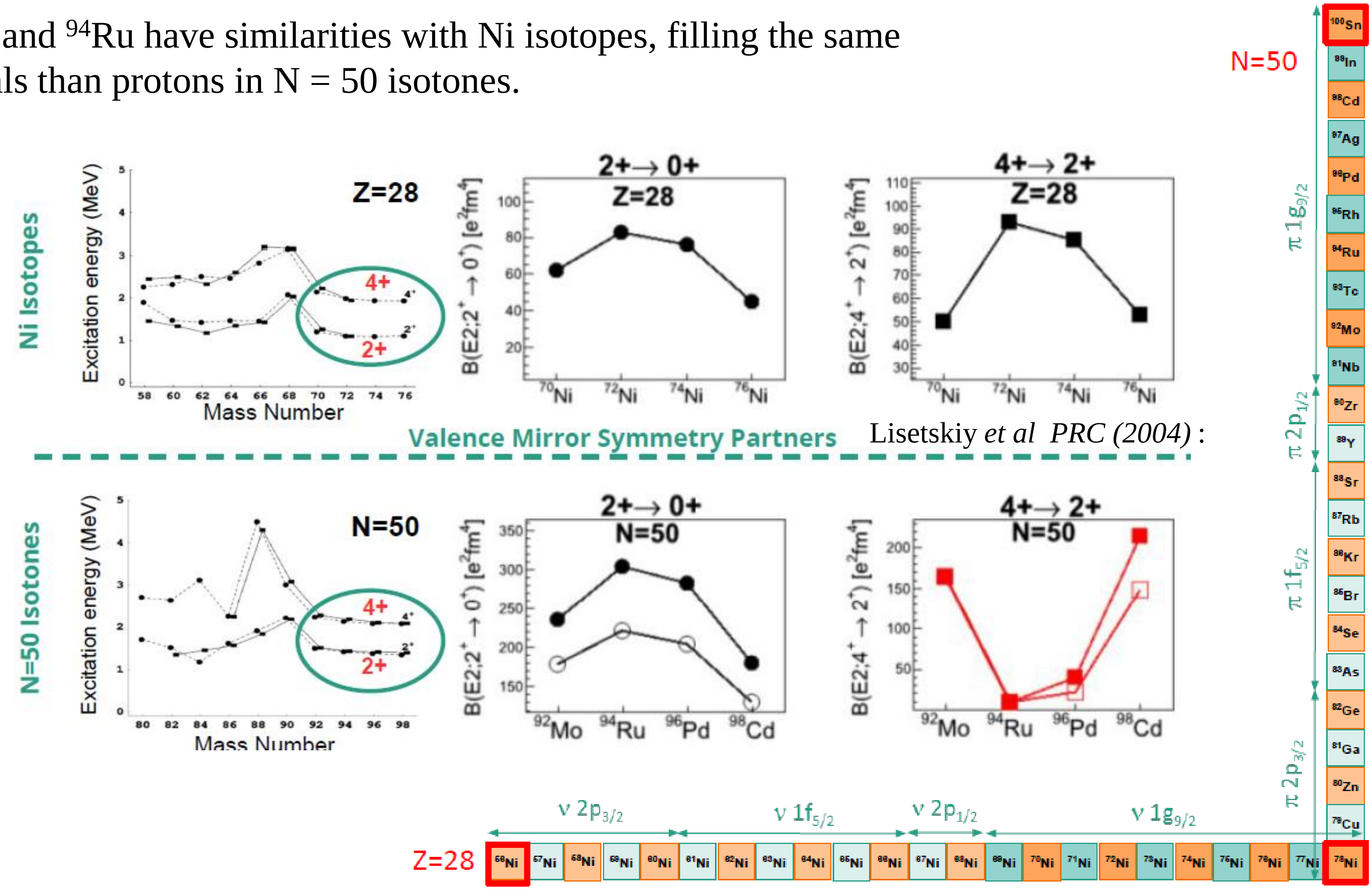
M. Lettmann et al. Phys.Rev. C 96, 011301 (2017)



F. Didierjean (IPHC)

Shell evolution around ^{100}Sn

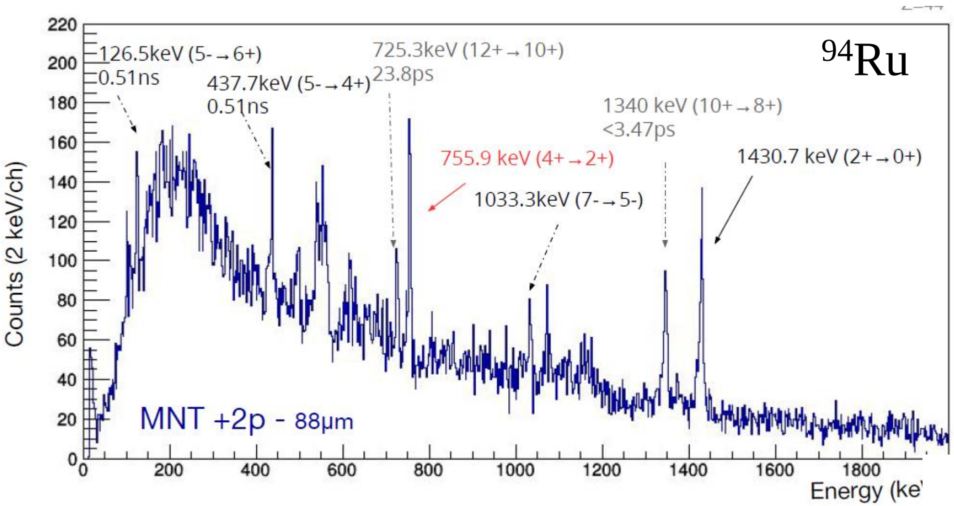
^{92}Mo and ^{94}Ru have similarities with Ni isotopes, filling the same orbitals than protons in N = 50 isotones.



Lisetskiy *et al PRC (2004)* :

courtesy of R. Perez Vidal

Shell evolution around ^{100}Sn



Shell model theory in the proton valence space

$f_{5/2}, p_{3/2}, p_{1/2}, g_{9/2}$

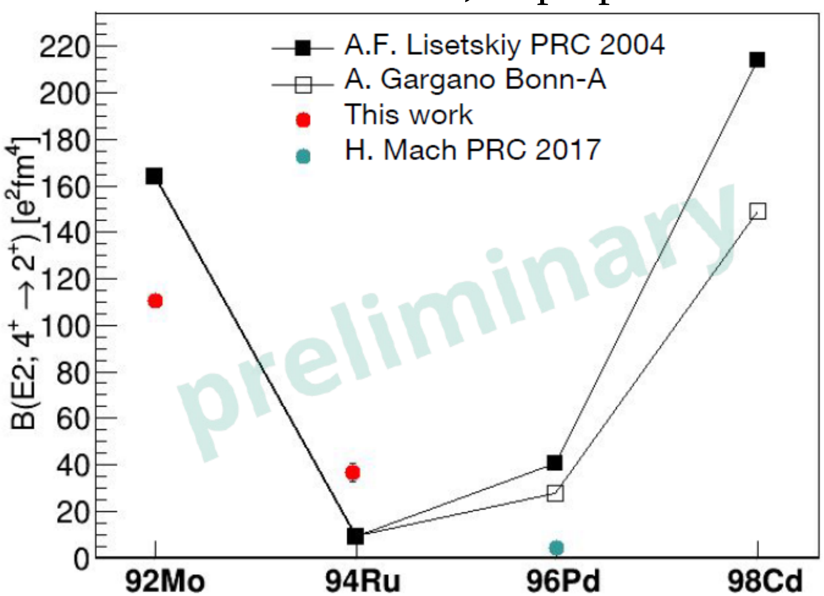
A. F. Lisetskiy et al. PRC 2004

- Bonn-C
- $e_p=2$

A. Gargano (private comm 2014)

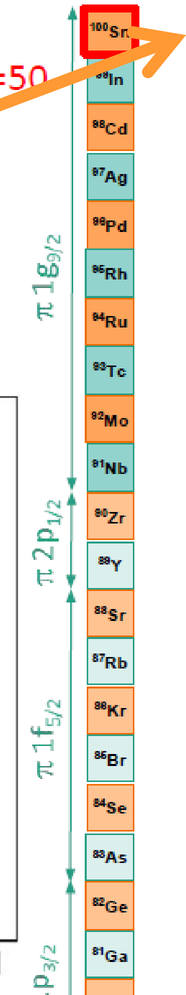
- Bonn-A
- $e_p=1.55$

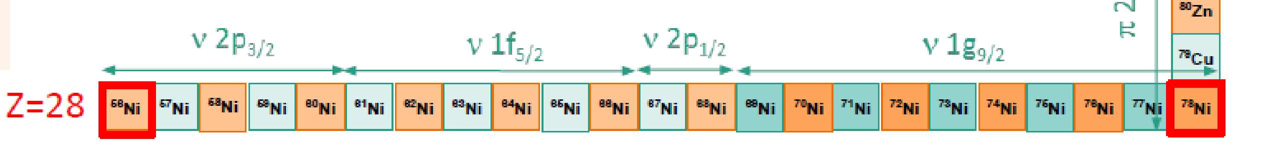
R. Perez Vidal et al, in preparation



$^{106-108}$Sn $2^+,4^+$

M. Siciliano, et al. (LNL)





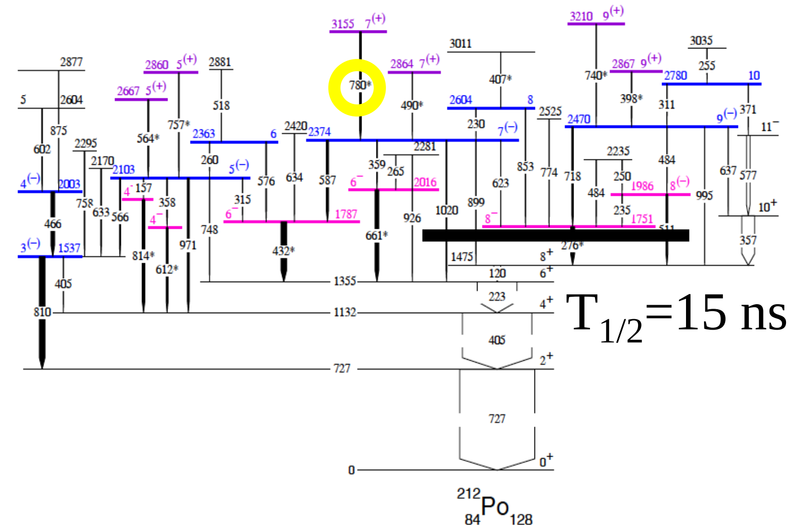
E.Clément

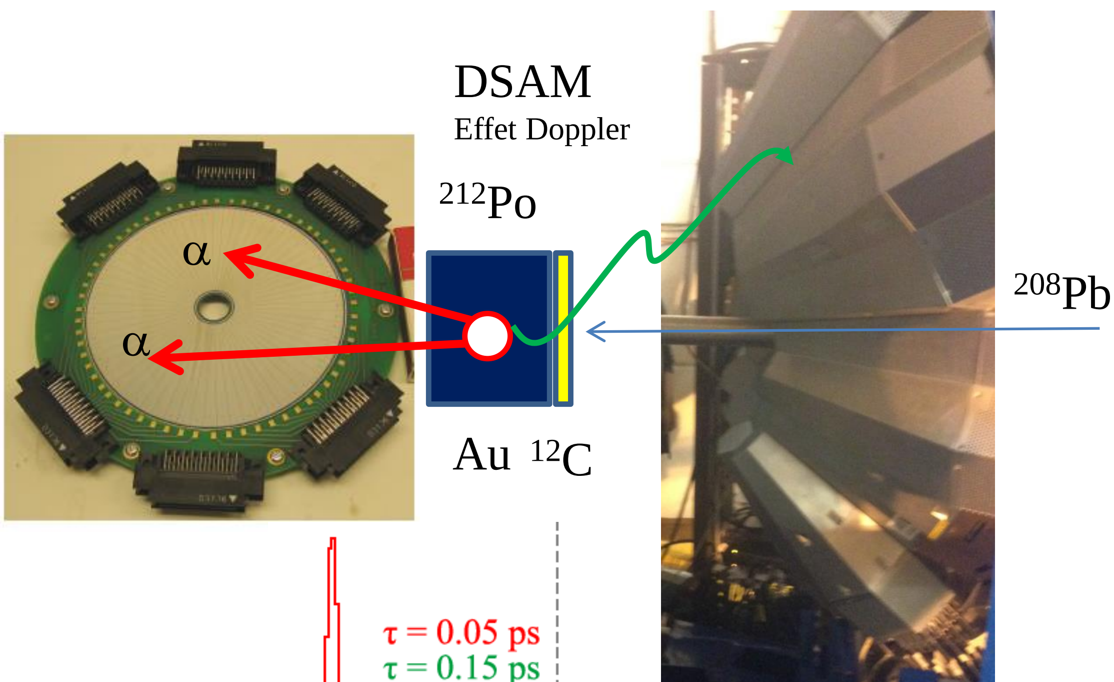
courtesy of R. Perez Vidal

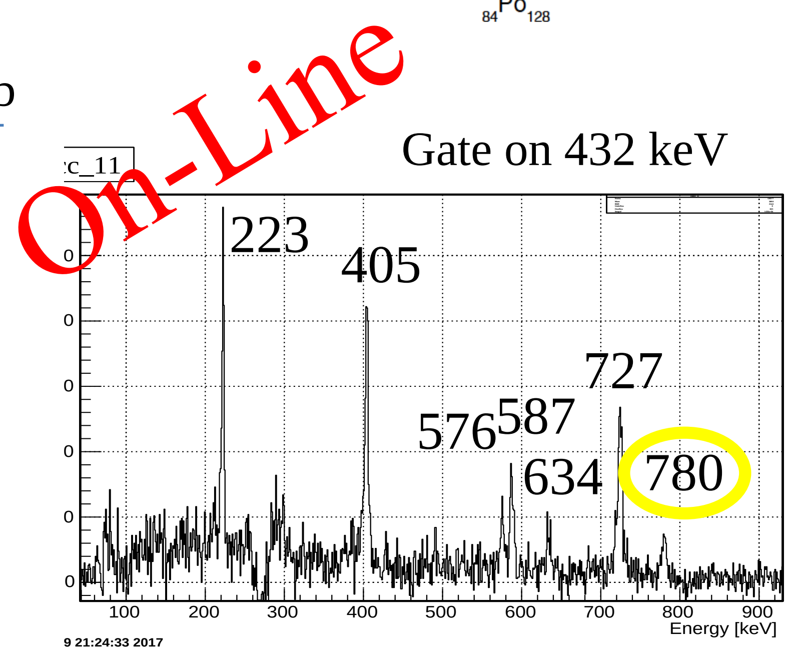
Cluster Structure

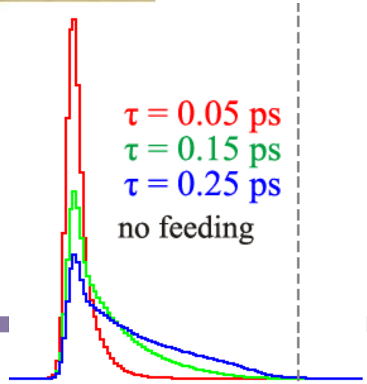
Search for the alpha cluster structure in heavy elements: case of ^{212}Po ($^{208}Pb+\alpha$) using the $^{12}C(^{208}Pb,^{8}Be)^{212}Po$ reaction. Lifetime measurement of the non-yrast states using the DSAM method

A. Jungclaus, A. Astier et al, 2017 Data





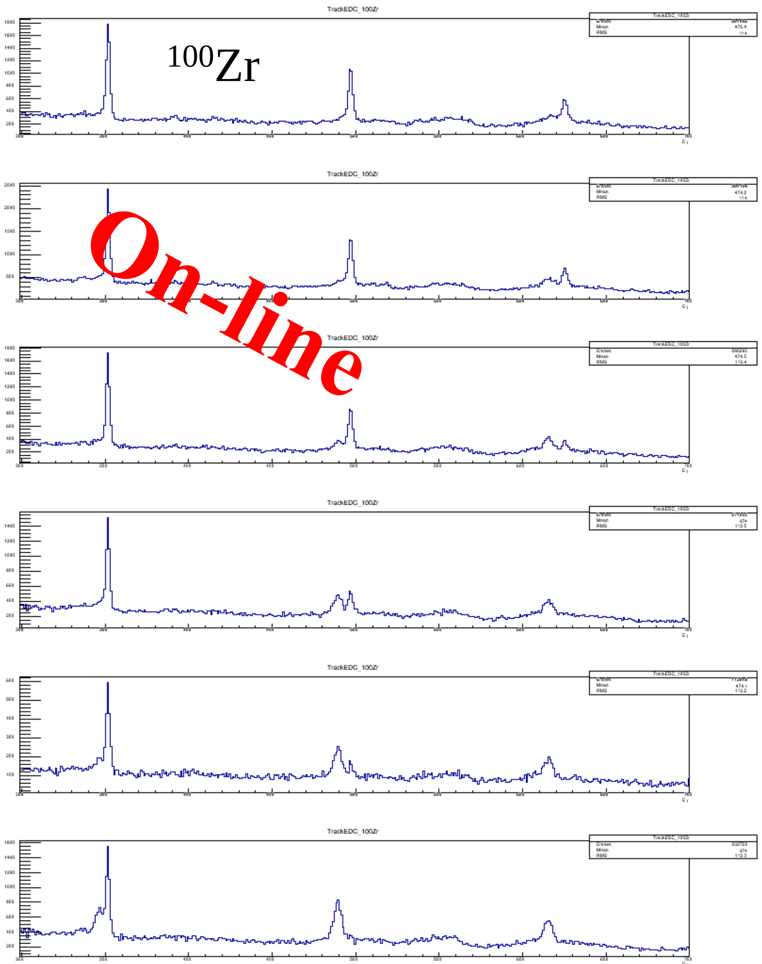


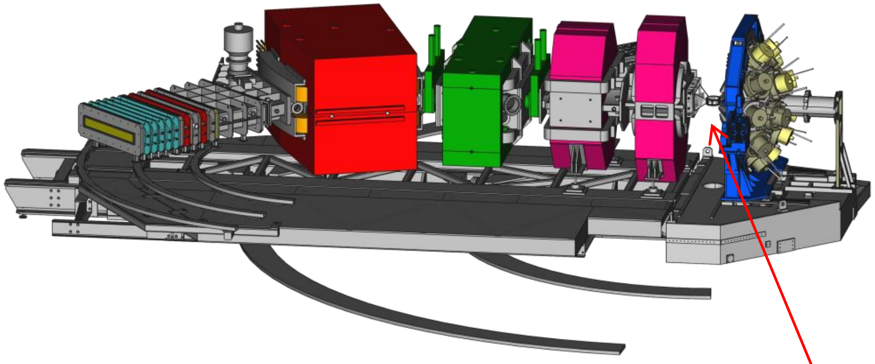


Shape evolution in fission fragments in the A~100 region

AGATA-VAMOS and a plunger + FATIMA for lifetime measurements using the $^{9}Be(^{238}U,FF)$ reaction

W. Korten, A. Görgen et al, 2017 Data

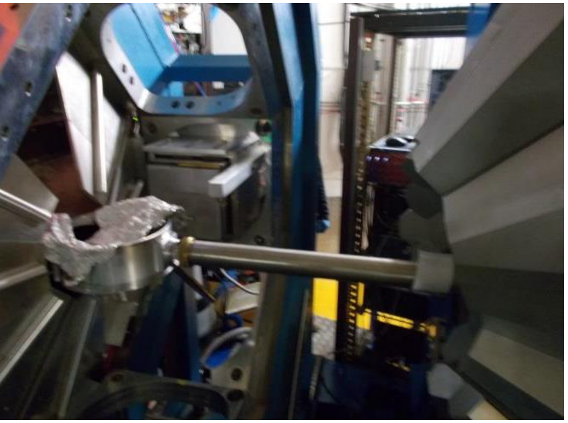


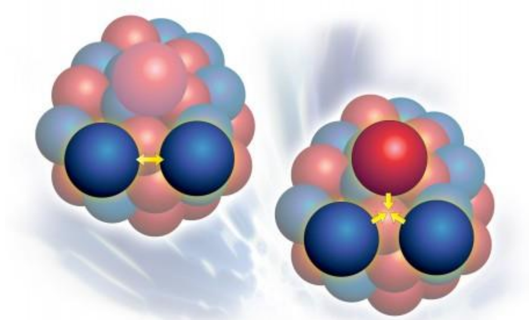


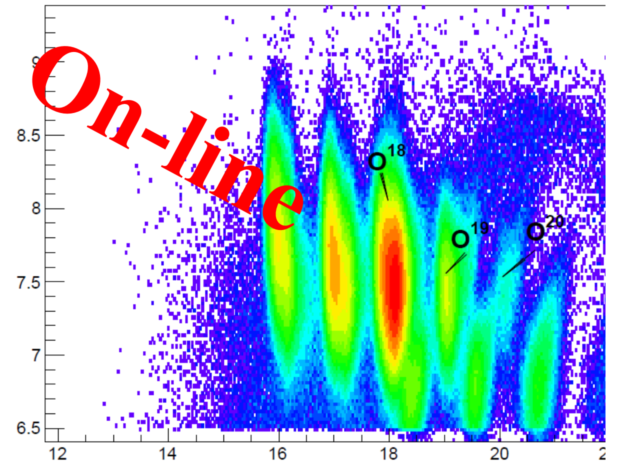
+ Plunger (short lifetime $I^{\pi} > 4^{+}$)

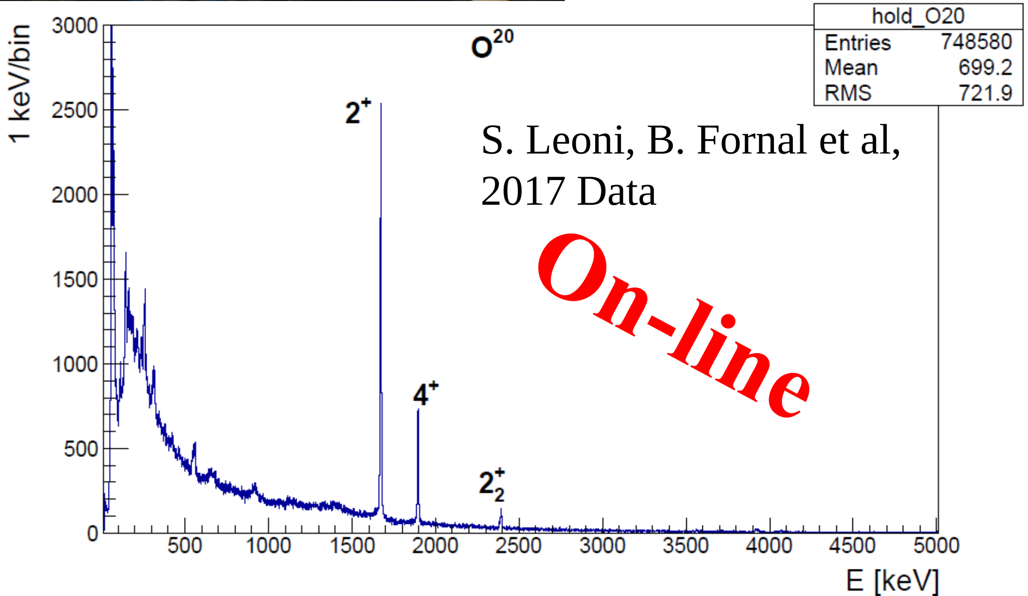
3-body contribution

Lifetime measurement in the non-yrast excited states of neutron rich C and O isotopes to probe the 3 body- contribution in the nuclear interaction using the ^{198}Pt/Tl(^{18}O, ^{16,18}C, ^{20}O) reaction. Branching ratio using the PARIS array and ideally E2/M1 ratio will be measured









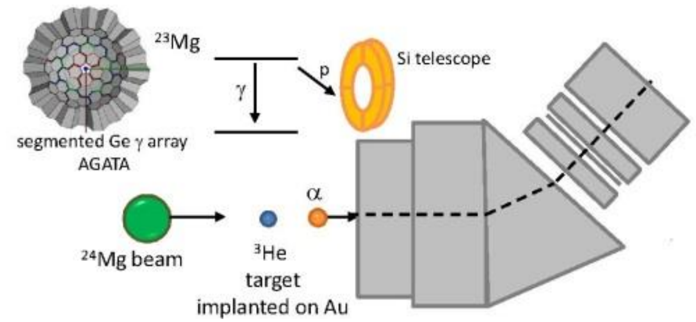
		Interactions				
Nucleus	Excited state	lifetime τ [ps] (*ab initio* NN)	lifetime τ [ps] (*ab initio* NN+ NNN)	mixing ratio δ (E2/M1) for $2^+_2 \rightarrow 2^+_1$ (*ab initio* NN)	mixing ratio δ (E2/M1) for $2^+_2 \rightarrow 2^+_1$ (*ab initio* NN+NNN)	Experiment τ [ps]
^{16}C	2^+_1	24	24			11.4(10) - 18.3(50)
	2^+_2	0.23	0.08	0.30	0.08	< 4
^{18}C	2^+_1	19.4	20			22.4(3.5)
	2^+_2	2.2	1.1	0.02	0.04	< 4.6
^{20}O	2^+_1	10,3	11,7			10.70(40)
	2^+_2	0.32	0.20	0.24	0.04	-
^{22}O	2^+_1	0.40	0.46			0.69(28)
	2^+_2	0.064	0.043	0.33	0.05	-

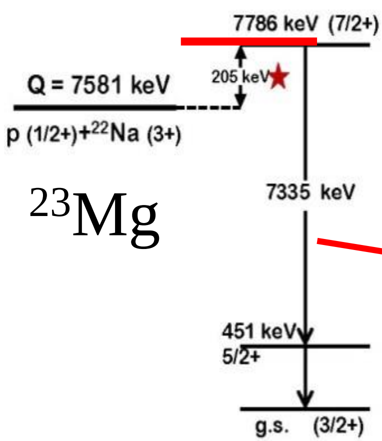
Nuclear Astrophysics

C. Michelagnoli, F de Oliveira et al,

The determination of the rate of destruction of ^{22}Na is crucial for nova models

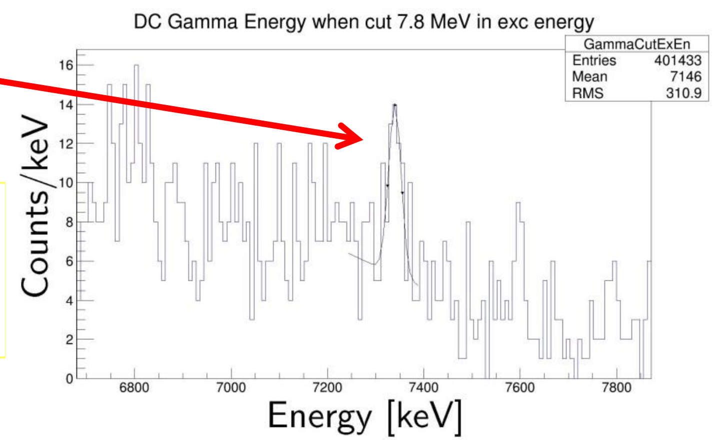
^{24}Mg(^{3}He,αγ)^{23}Mg





^{22}Na(p,γ)^{23}Mg

dominated by the resonance at 205 keV above threshold



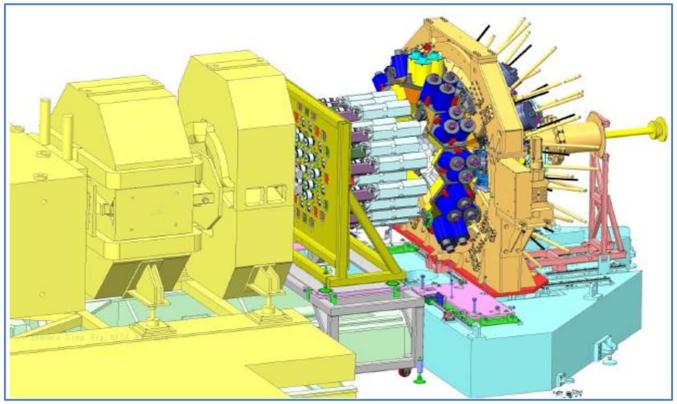
Measurement: lifetime of the 7.786 MeV state in ^{23}Mg, exploiting the position sensitivity of AGATA using the Doppler Shift Attenuation Method

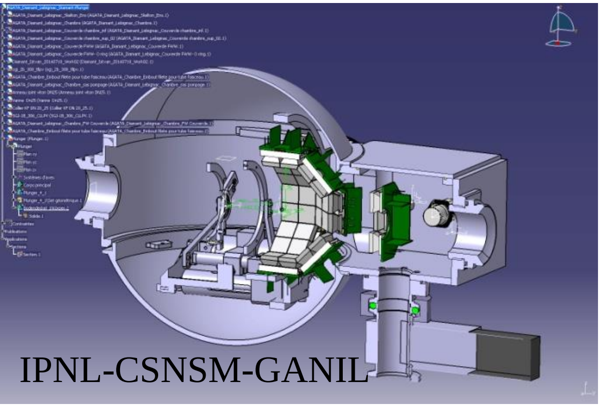
The lifetime and proton branching ratio obtained from the same experiment will provide a precise determination of the rate of the ^{22}Na(p,γ)^{23}Mg reaction

courtesy of C. Michelagnoli

2018 run *NEDA campaign*

8 experiments approved using AGATA+NEDA (+DIAMANT) (+LaBr3) (+plunger)





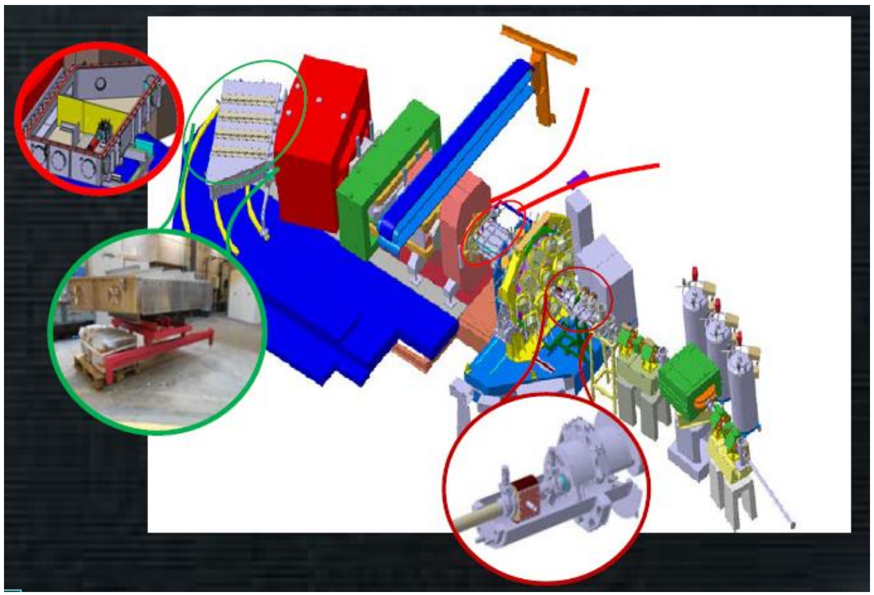
The mechanical design foresees the use of 54 self produced NEDA detectors at forward angles and 14 NWALL detectors at around 90 degrees coupled to DIAMANT, using the NUMEXO2 FEBEE

Pre-installation in G2 with in-beam tests foreseen during run 3

Start of the campaign : Early 2018 –

2019-(2020) run *MUGAST-GFM*

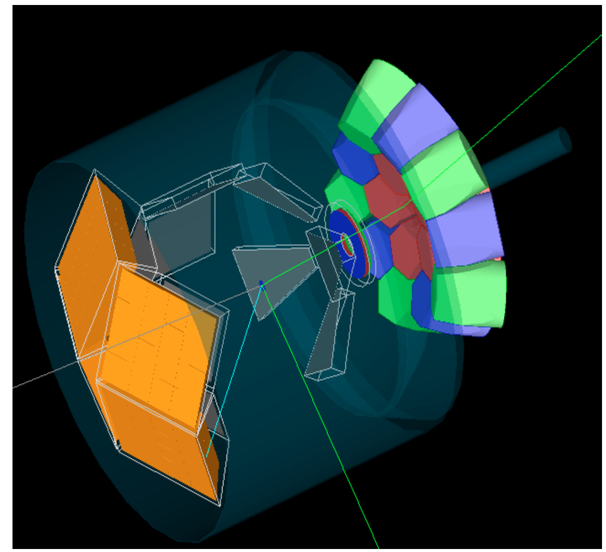
VAMOS in GFM



The project will be completed in 2017 and ready for commissioning.

- In-beam spectroscopy of heavy elements and N~Z nuclei

Nucleons transfer spectroscopy using SPIRAL1 ISOL beams



Nuclear Astrophysics: spectroscopic factors of relevant resonances for nucleosynthesis studies in radiative capture reactions: (^{6}Li,d), (^{3}He,d), (d,p)

Shell evolution:
spectroscopic factors, s.p. energies (d,p), (t,p), p-n pairing, clusterization