AGATA@GANIL
Status report

AGATA week 2018

E.Clément

The GANIL Campaign organization

The AGATA campaign at GANIL has been extend to the end of 2020

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 in 2017: Fully opened by the new GANIL management : 2(1) VAMOS (MUGAST) approved

- Pré-PAC in February 2018 :
  - 12 MUGAST/Coulex with SPIRAL1 beams
  - 6 Gas-Filled
  - 5 NEDA-DIAMANT
  - 3 VAMOS Std

853 UT have been already approved
628 UT have been performed over 22 experiments

- 5th PAC in Autumn 2018: call for MUGAST-AGATA-VAMOS experiments only
  - 5 MUGAST-AGATA-VAMOS experiments proposed

Thanks to Silvia for her work in the scientific coordination of the campaign since 2012

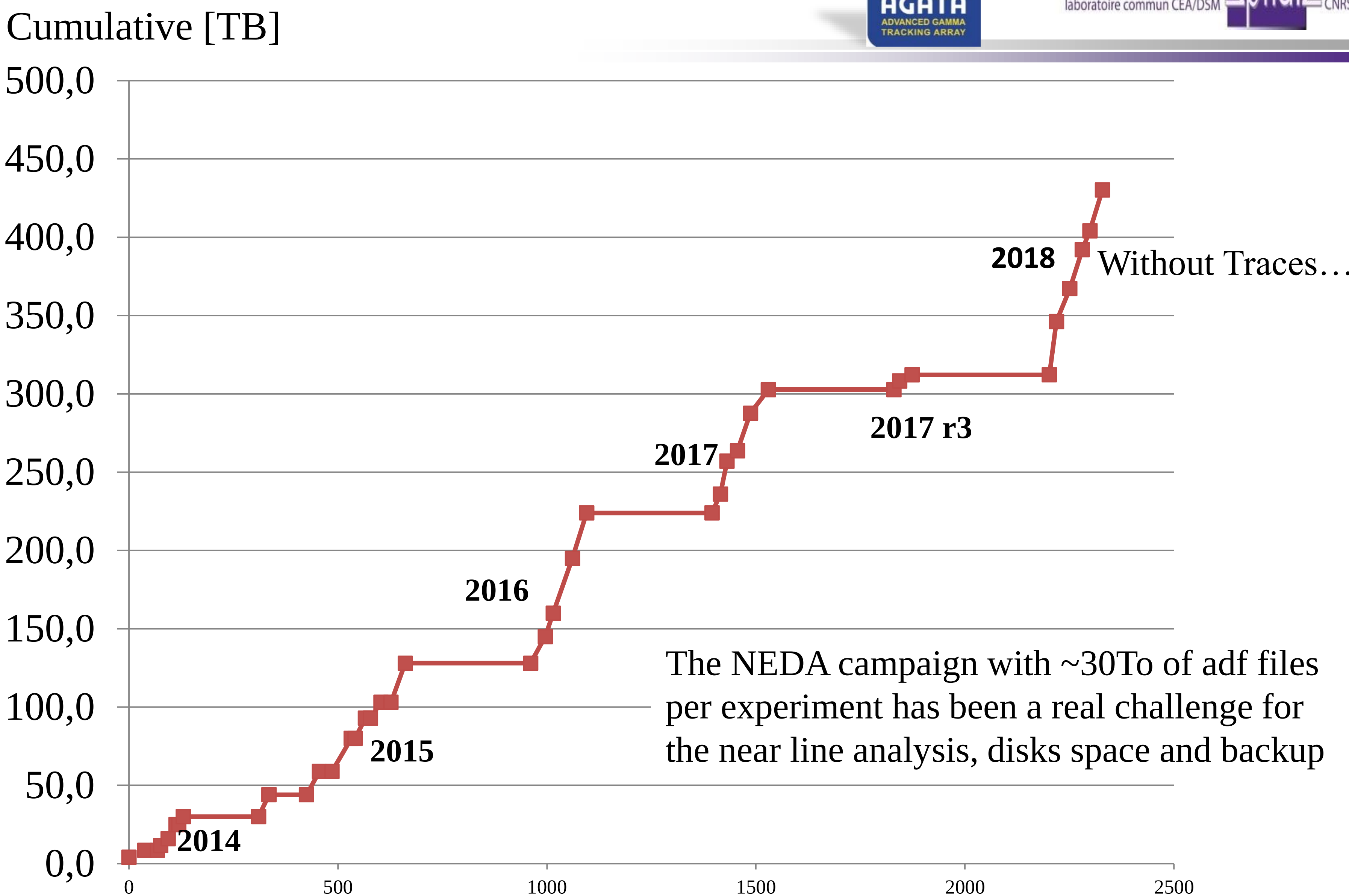
Backlog is
1 PARIS-DIAMANT 28 UT
3 NEDA (+ DIAMANT, PARIS, FATIMA) 66 UT
4 VAMOS 92 UT
1 MUGAST 39 UT + Re-schedule of a failed 2018 LISE exp.

- 2019 beam time should be ~4 months

2018 Technical achievements

- ❑ Data Acquisition NARVAL → DCOD: process full real-time w/o PSA from 6 to 12kHz per core
- ❑ Improved PCIe readout libraries for both GGP and LINCO2
- ❑ Successful integration of NUMEXO2 and its TP in AGATA via the GTS and the DCOD/TM/RCC systems
- ❑ Learning curve in the CEPH technology
- ❑ Data analysis and access to the data
  - * Improved access to the GRID data
  - * Successful integration of NEDA and DIAMANT in the AGATA data processing
  - * 2nd Data Analysis Workshops in January 2018
  - * 3rd focused on the NEDA-DIAMANT-AGATA campaign in early 2019
- ❑ Efficiencies
  - *Lot of efforts on source and in-beam efficiencies studies devoted in 2017
  - * In 2018, we focused our attention on the high rate-capabilities approaching the hardware/software limits

- ❑Operation
  - *We ran 22 experiments in ~11 months of beam time (~2 experiments/month)
  - *35 Detectors take data since 2017 in stable conditions
  - *There are 1330 electronics channels to manage (Detectors, FEBEE, DAQ, calibrations)
  - *~60 000 parameters are prepared to reach the final spectrum
  - * 430 To of data produced including the 2018 run
  - *In-beam data since 2014, the campaign is approved until 2020 (7 years operation)
  - *Detectors maintained cold for more than 1200 days without accidental warming up



The NEDA campaign with ~30To of adf files per experiment has been a real challenge for the near line analysis, disks space and backup

Long term Visitors

Visitors 2014-2015

A. Korichi (CSNSM)- GANIL Support – (18 months)

R. Perez (IFIC) – Spain and GANIL support (3 months)

C. Andreoiu (Simon Fraser University) – Canada and GANIL support (6 months)

Visitors 2016

M. Zielinska (SphN) – GANIL/SPhN Support (6 months)

R. Perez (IFIC) – Spain and GANIL support (3 months)

Visitors 2017

M. Zielinska (DphN) – GANIL/DPhN Support (4 months)

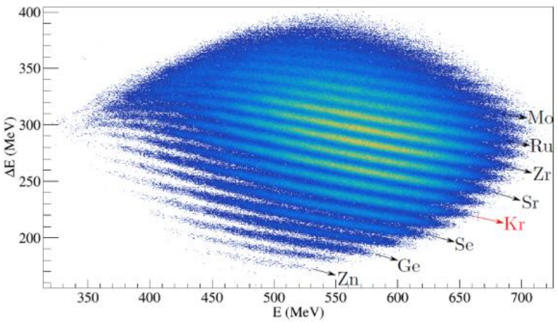
G. Simpson (LPSC) – GANIL/LPSC Support (4 months)

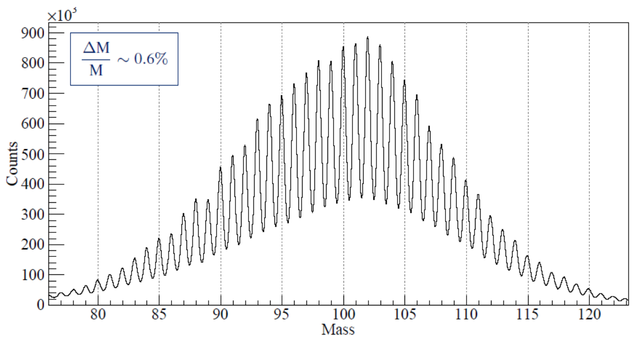
Visitors 2018

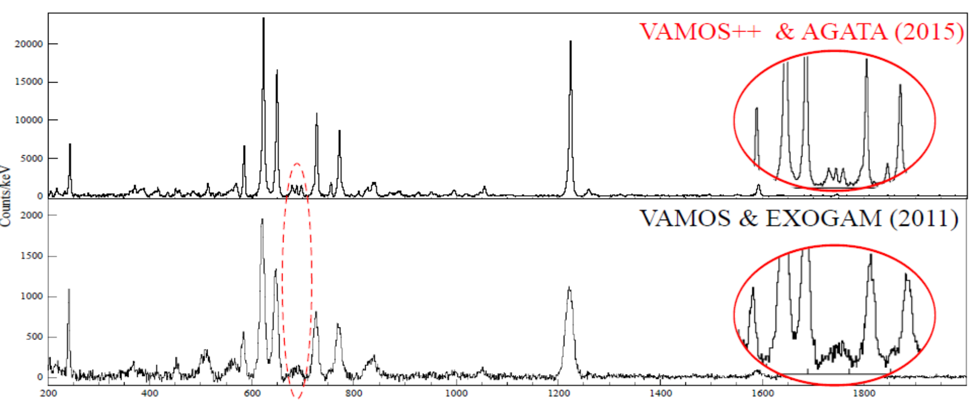
M. L. Jurado (IFIC) – Spain support (4 months)

The GANIL Campaign [2015-2020]

Courtesy J. Dudouet





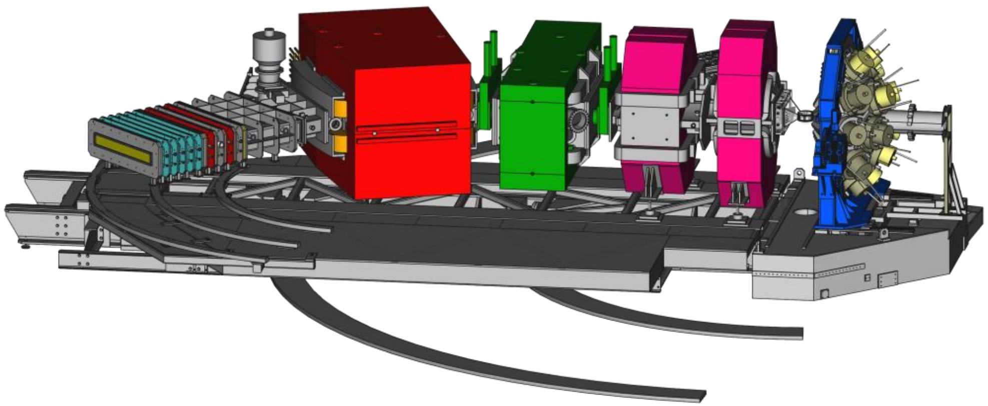


2017-2018 : 35 detectors on-line : Efficiencies measured in nominal position at 1.408 MeV

Core 3.4(1)% (GEANT4 = 3.6%)

AddBack 4.8(1)% (5.1%)

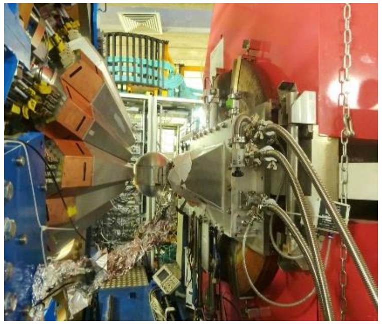
Tracked 4.4(1)% (5.5%)

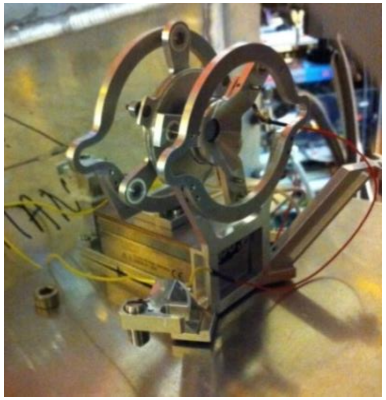


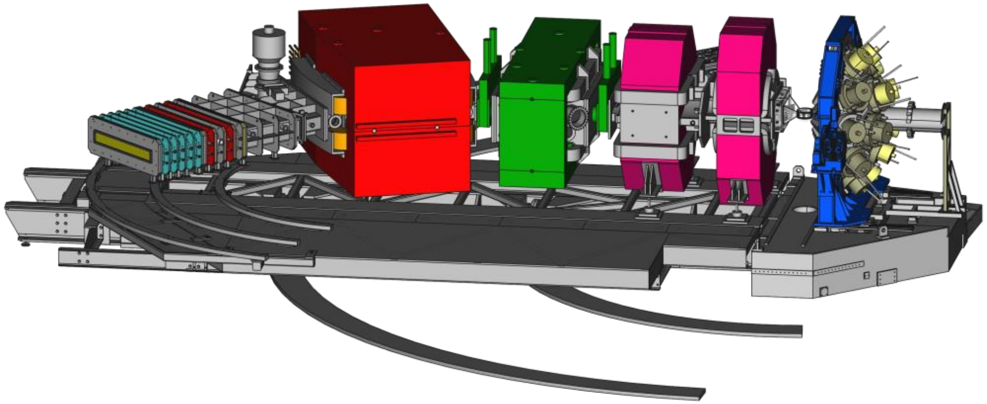
- ✓Nucleons transfer
- ✓Fusion-fission
- ✓Transfer-fission

E. Clément et al., NIMA 855, 1-12 (2017)
Y. H. Kim et al., Eur.Phys.J. A 53, 162 (2017)

The GANIL Campaign [2015-2020]

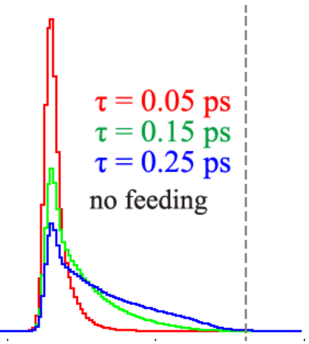




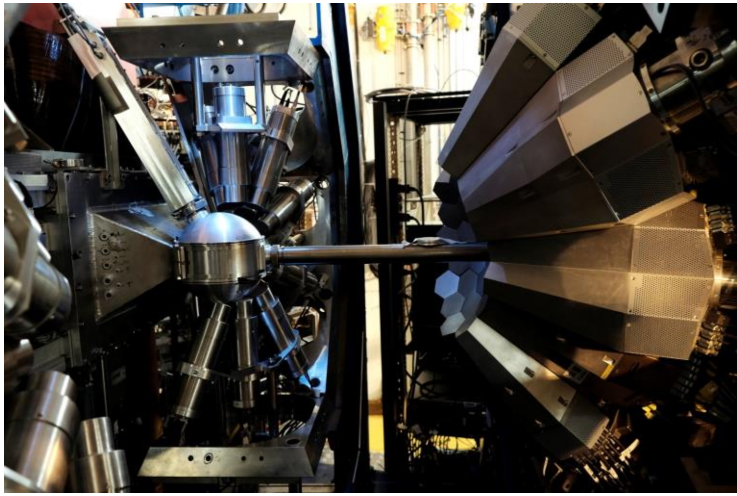


Lifetime measurements

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



E. Clément et al., NIMA 855, 1-12 (2017)
Y. H. Kim et al., Eur.Phys.J. A 53, 162 (2017)



FATIMA-PARIS detectors coupled to AGATA

The GANIL Campaign [2015-2020]

2018 run NEDA campaign

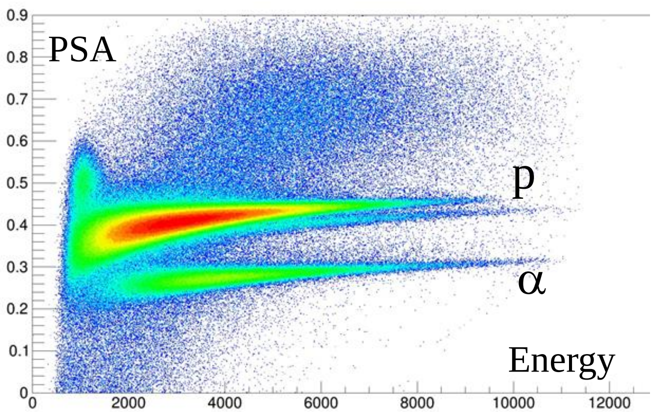
DIAMANT and NEDA in full digital system making use of the NUMEXO2 boards and coupled to AGATA with the AGATA GTS system

×20 increase in (nγ²) event rate readout compared to the NWALL-DIAMANT-EXOGAM system in VME-VXI.

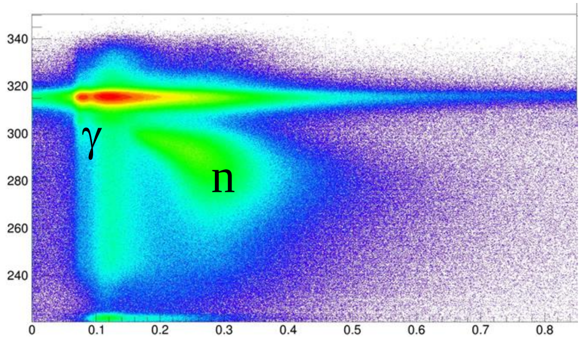
T. Huyuk et al, Eur. Phys. J. A (2016) **52**: 55 Page 5

E. Clément et al., NIMA 855, 1-12 (2017)

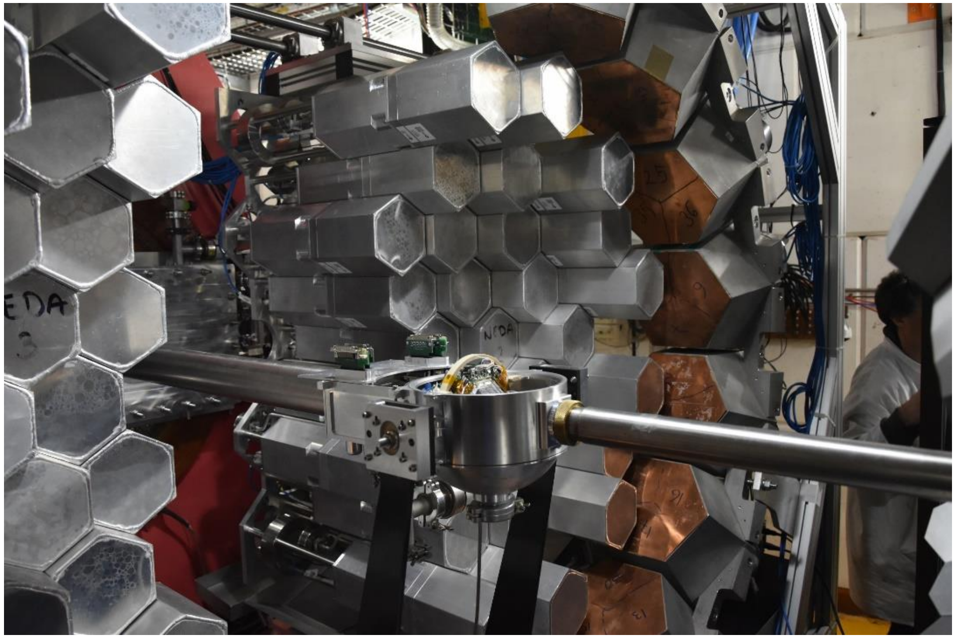
J. J. Valiente-Dobon et al, to be submitted



Time of flight



PSA – Neural network



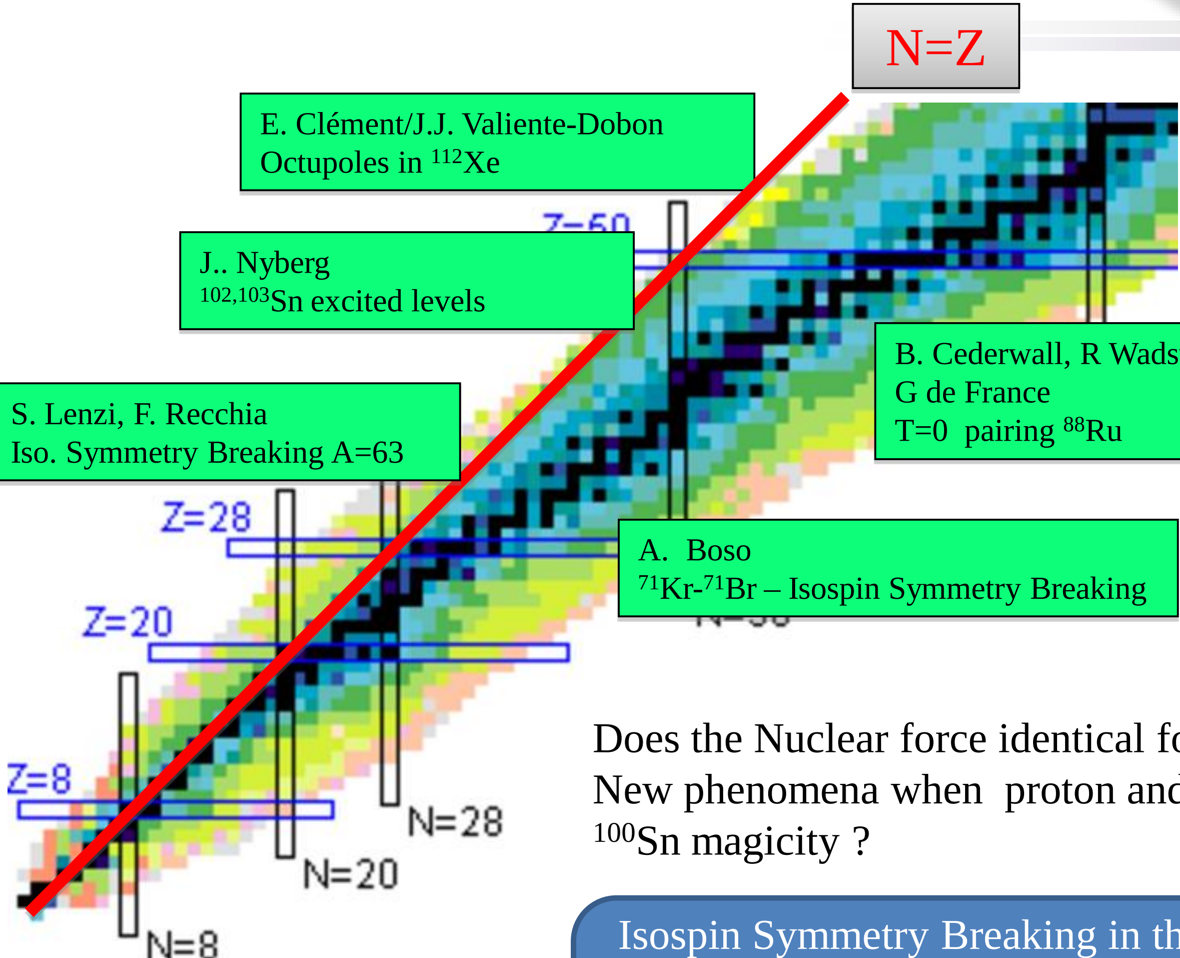
54 self produced NEDA detectors at forward angles and 14 NWALL detectors + plunger

~9% γ-efficiency at 1.4 MeV after tracking

>20% efficiency for 1 neutron

>35% efficiency for 1 proton

Physics of N~Z nuclei



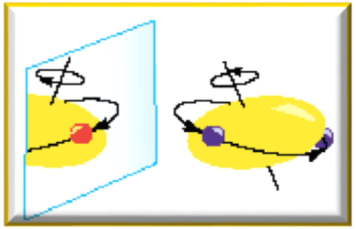
E. Clément/J.J. Valiente-Dobon
Octupoles in ^{112}Xe

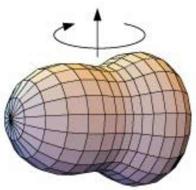
J.. Nyberg
$^{102,103}Sn$ excited levels

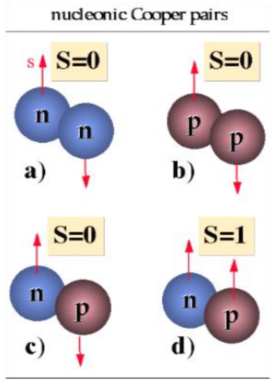
S. Lenzi, F. Recchia
Iso. Symmetry Breaking A=63

B. Cederwall, R Wadsworth, G de France
T=0 pairing ^{88}Ru

A. Boso
^{71}Kr-^{71}Br – Isospin Symmetry Breaking



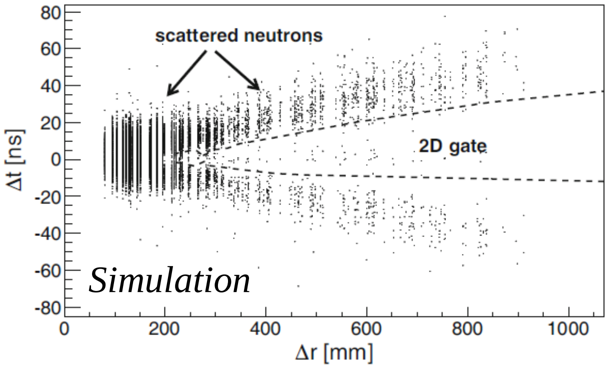




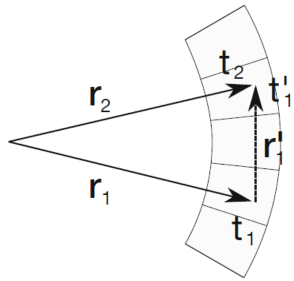
Does the Nuclear force identical for proton and neutron ?
New phenomena when proton and neutron occupy the same orbits ?
^{100}Sn magicity ?

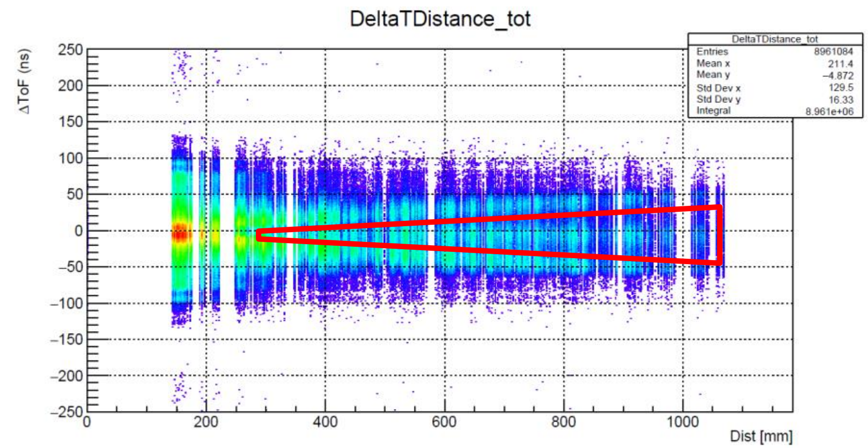
- Isospin Symmetry Breaking in the A=63,71 mirror nuclei
- Studies of excited states in $^{102,103}Sn$
- Search for isoscalar pairing in the N=Z nucleus ^{88}Ru
- Octupole – Quadrupole correlation in ^{112}Xe

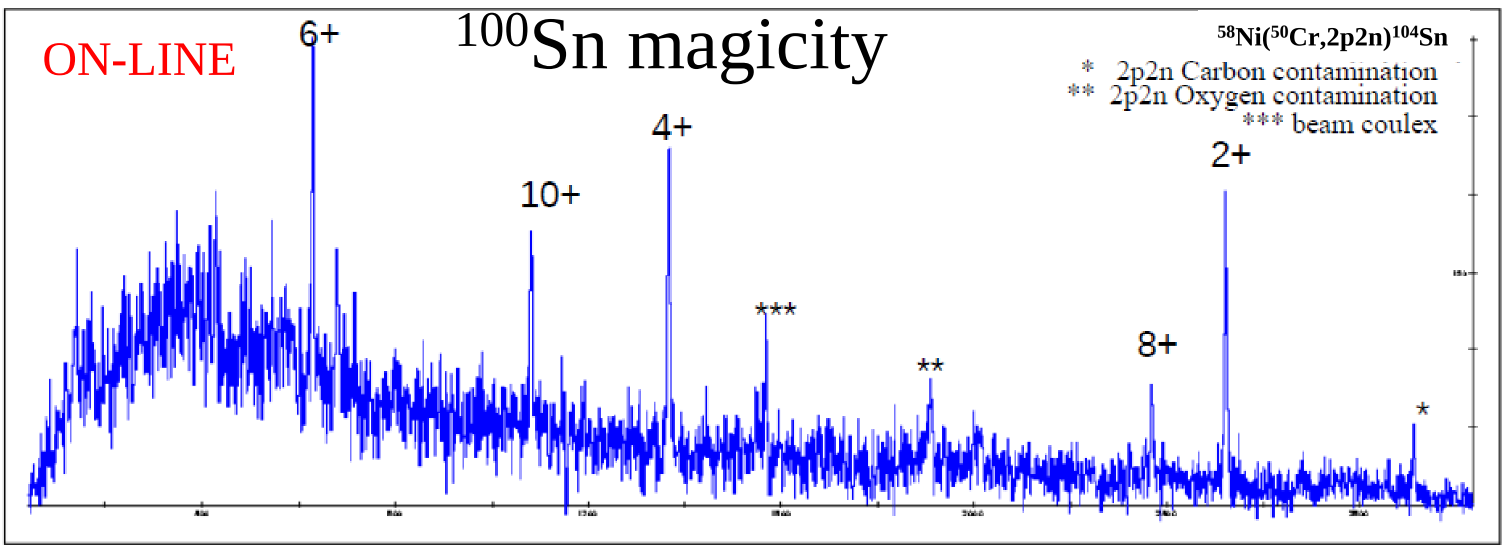
The NEDA setup : the 2n selectivity



T. Huyuk and the NEDA collaboration,
Eur. Phys. J. A (2016) **52**: 55 Page 5

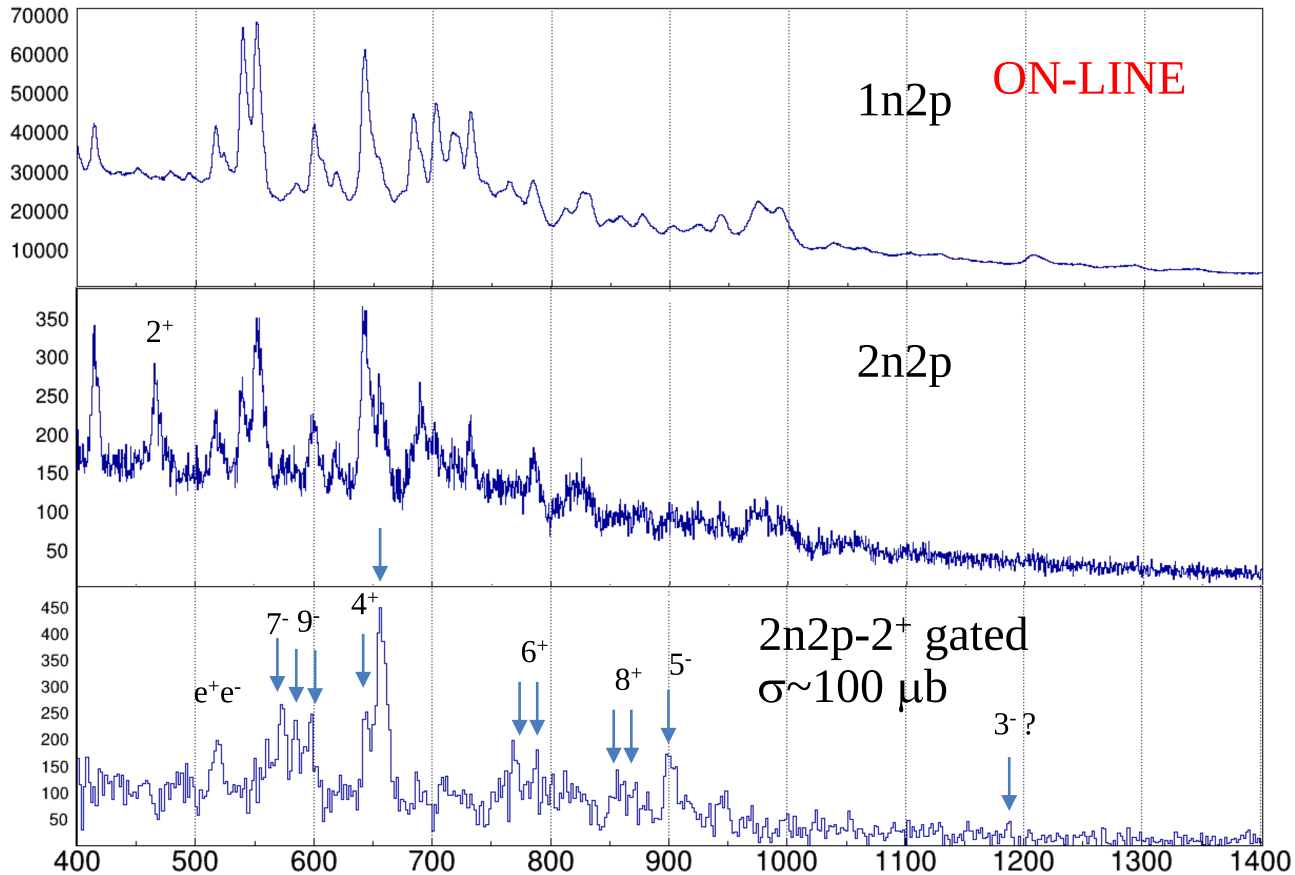


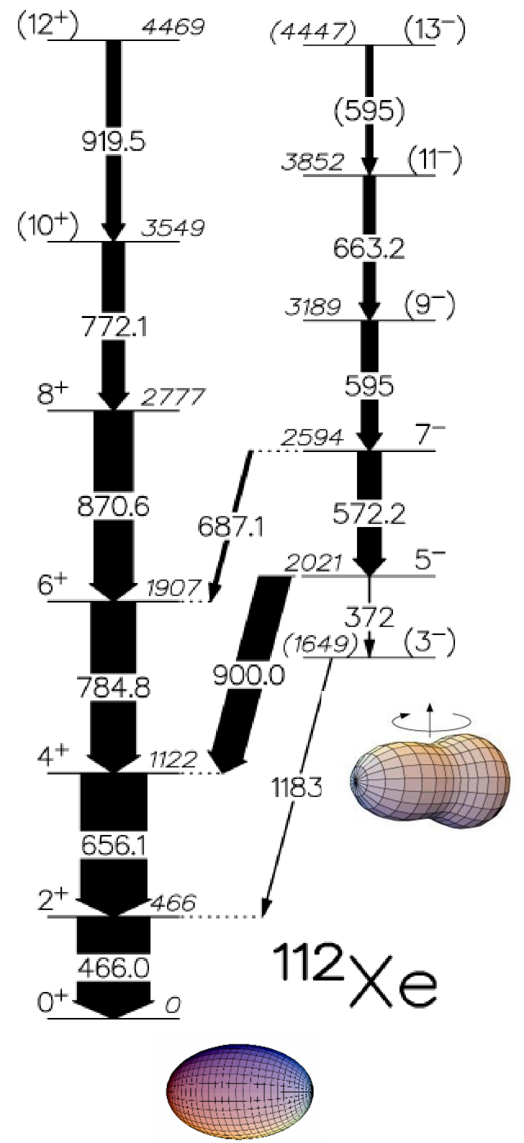




The NEDA setup : the 2n selectivity

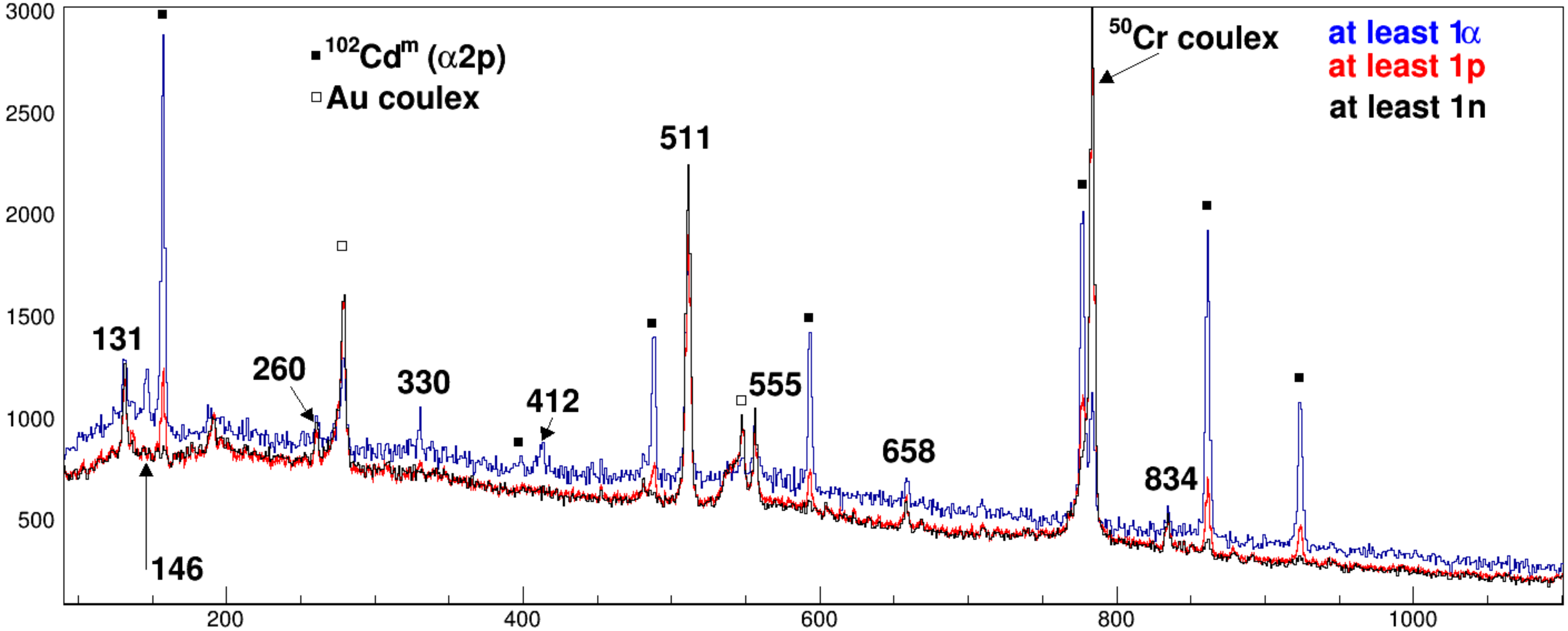
Lifetime measurement $^{58}Ni+^{58}Ni$ at 250 MeV

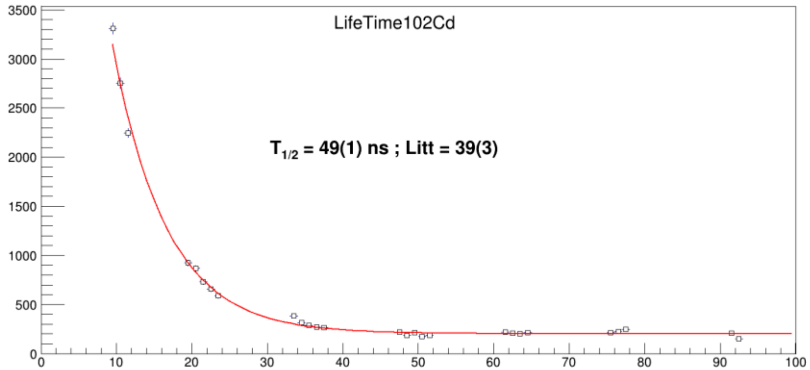


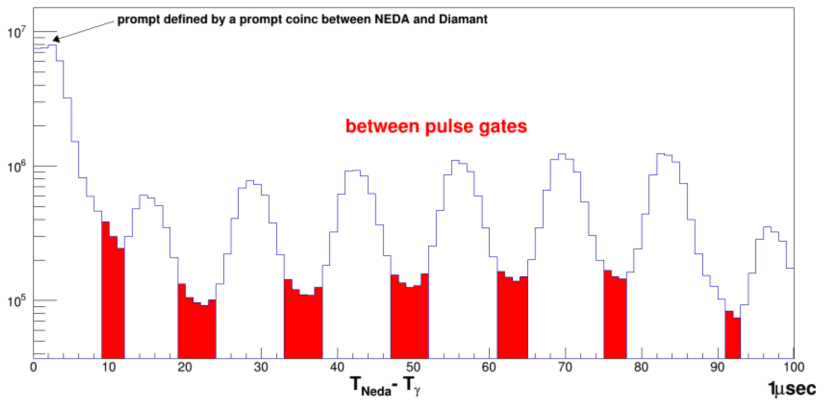


D. Ralet, M. L. Jurado, EC et al,
OUPS Plunger, J. Ljungvall et al, NIM A 679 (2012) 61-66. Degrader mode

The NEDA setup : the isomer selectivity



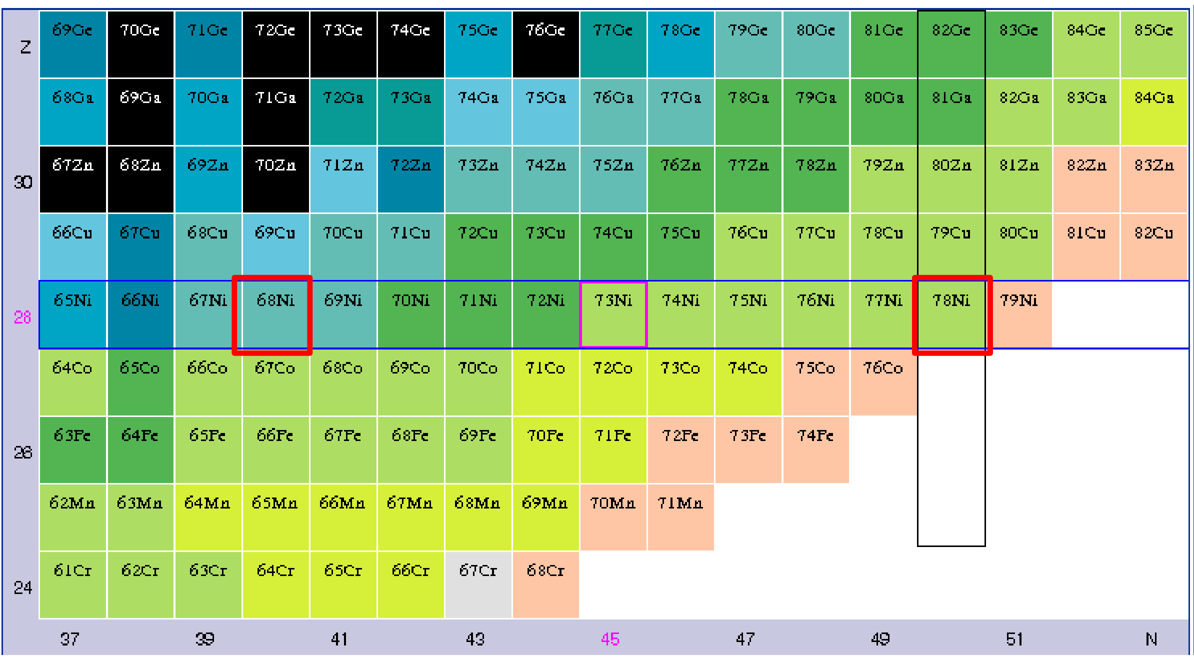


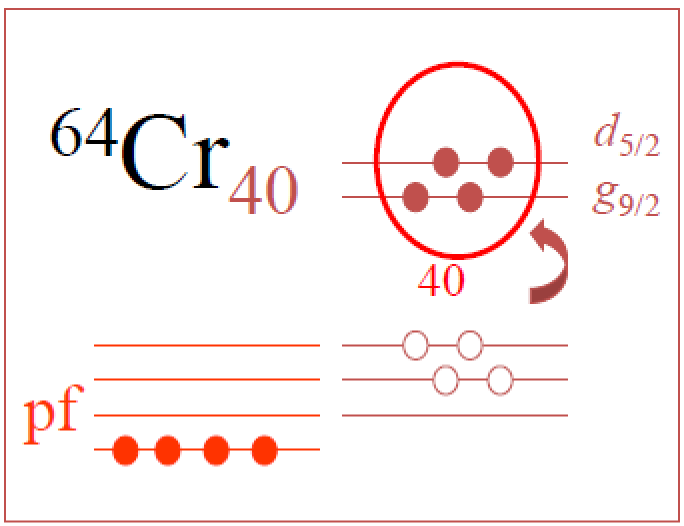


Shell evolution around Z=28

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 configurations 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 allow a better understanding of their properties by comparison with LSSM calculations





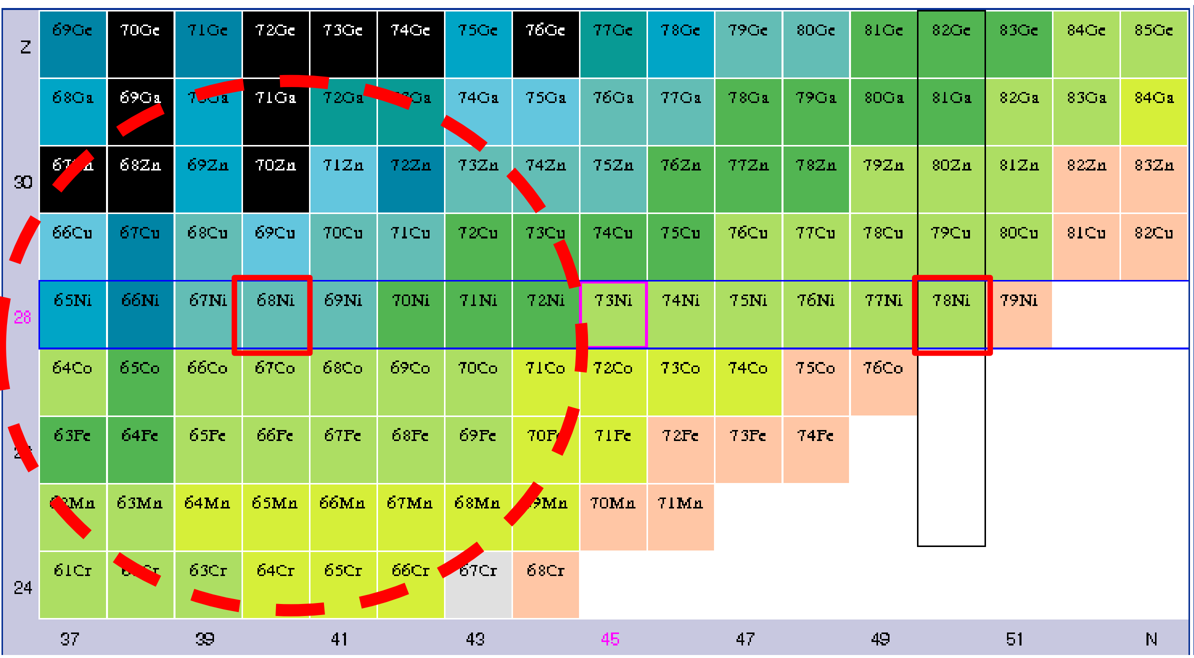
LPNS interaction

Shell evolution around Z=28

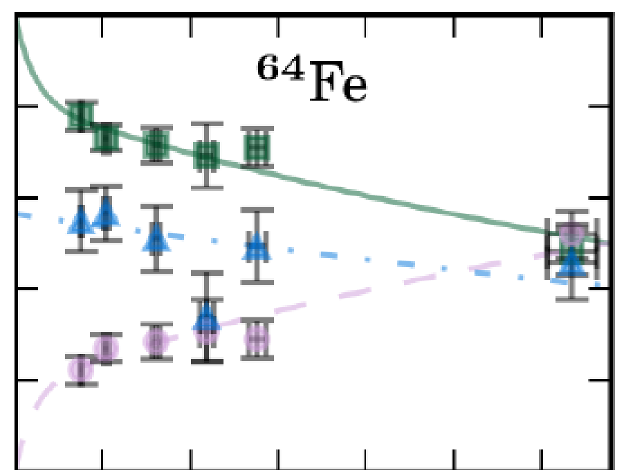
Interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe

Collecting spectroscopic data like transition probability constraining the theoretical description of the Island of inversion from N=28 to N=40 :

- What is the influence of the νg9/2 and νd5/2 orbits ?
- What is the influence of the proton excitations across Z=28 ?
- How collectivity change when decreasing the number of proton in the f7/2 orbital



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)

E.Clément

Shell evolution around Z=28

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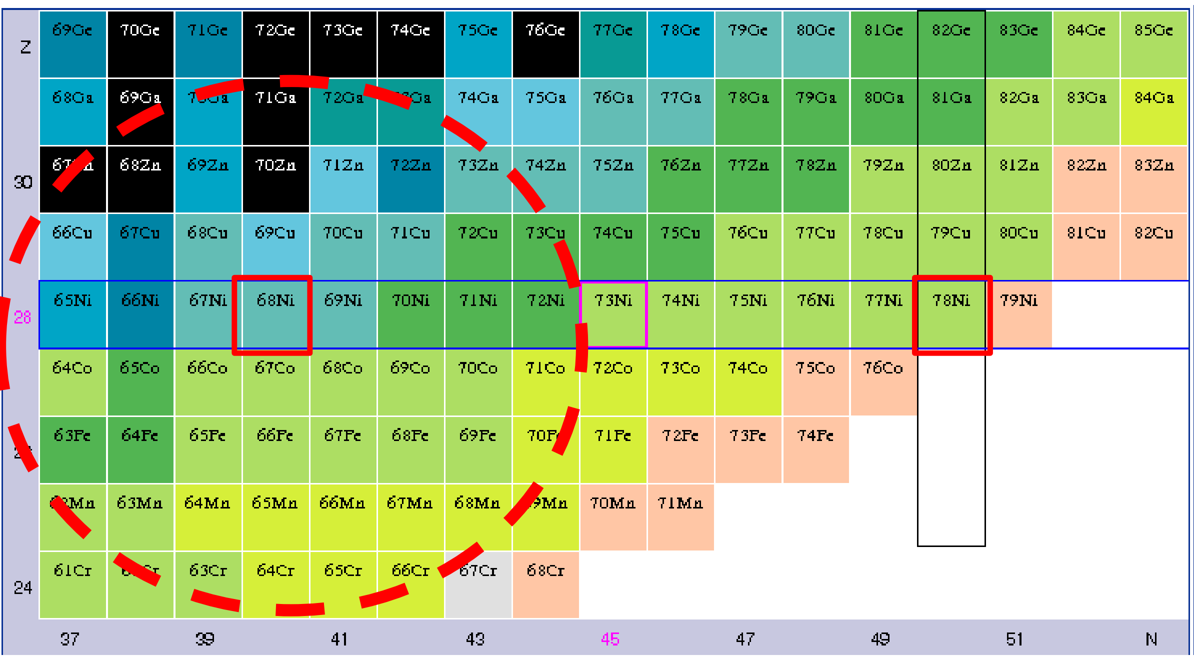
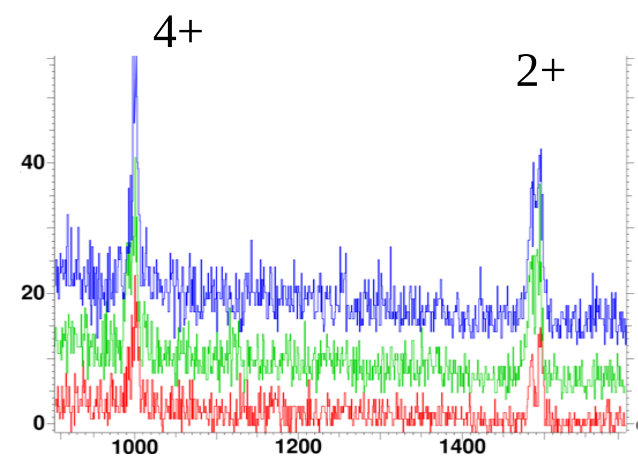


Lifetimes in ^{54}Ti and in neighboring isotopes have been determined

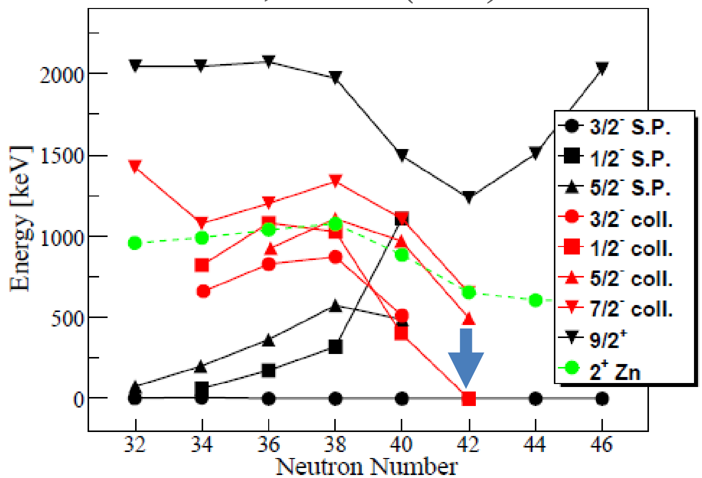


A. Goldkuhle et al. to be submitted

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

Dirken et al., PRC 82 (2010) 064309



^{73}Ga ground-state: $3/2^-$, $1/2^-$ doublet?

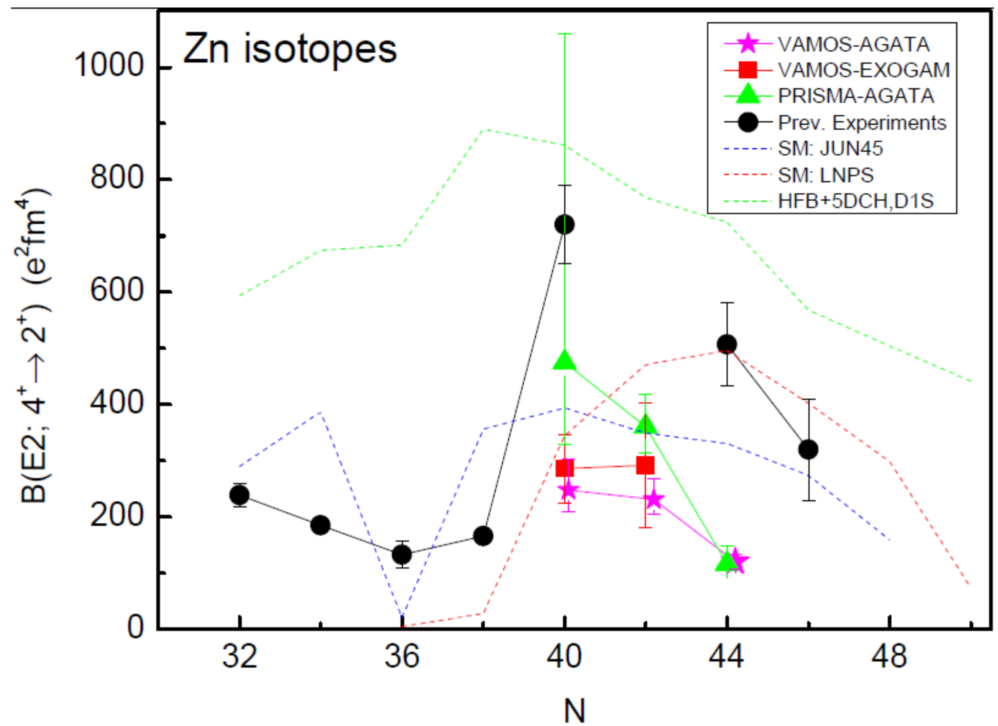
→ determine the M1 component of the first $5/2^-$

Obtained lifetime :

- Fast M1 component in the decay of the first $5/2^-$ state.
- Confirms $1/2^-$, $3/2^-$ g.s. doublet

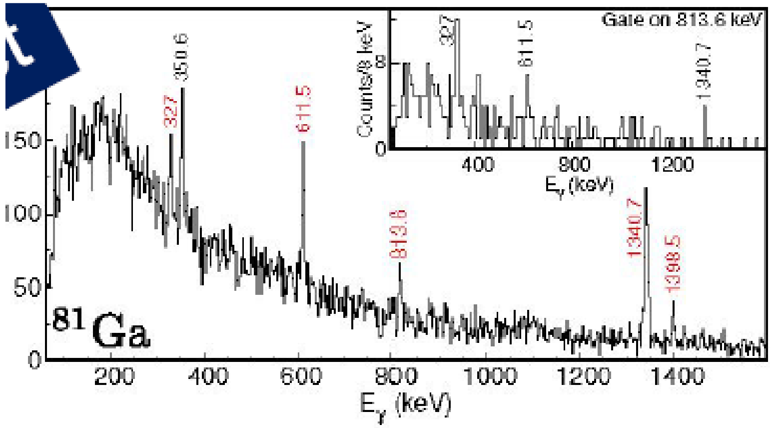
I. Čeliković, Ph.D. Thesis, GANIL 2013

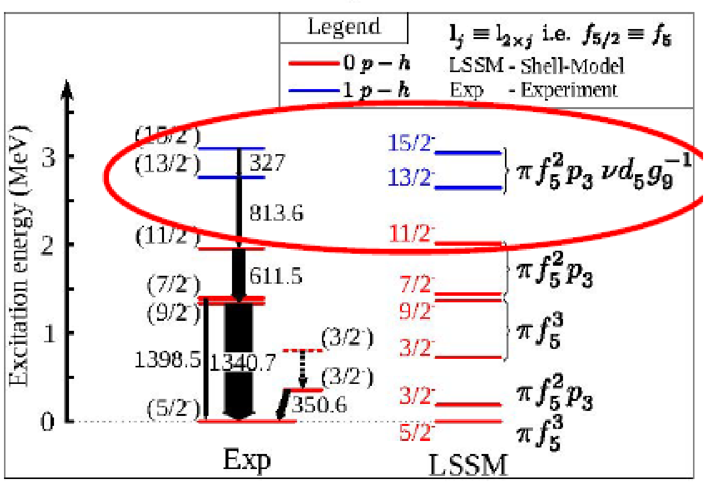
C. Louchart et al., Phys. Rev. C, 87 054302 (2013)



I. Celikovic, C. Michelagnoli et al.

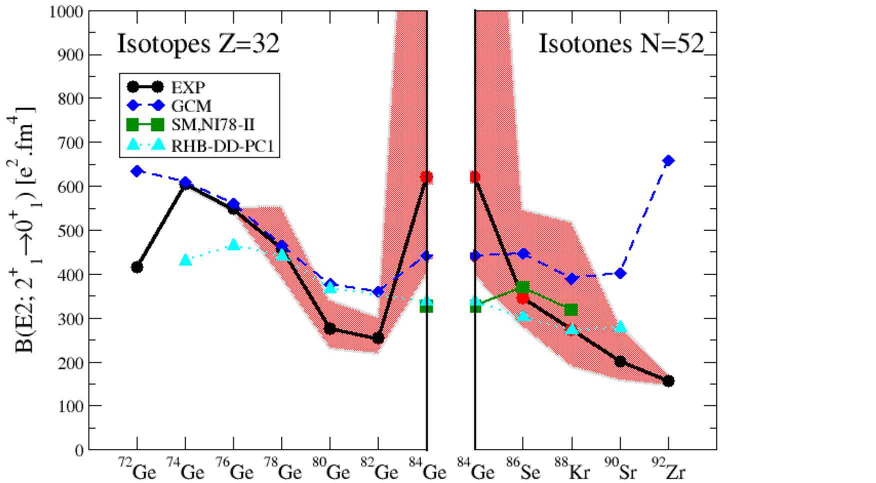
The quenching of the N=50 gap towards ^{78}Ni can be investigated looking at the Spectroscopy of excited states involving particle-hole excitations across the N=50 gap





- ^{81}Ga spectroscopy

J. Dudouet et al, to be submitted



- First lifetime of excited states measured in ^{88}Kr
- Lifetime measured with better accuracy in ^{86}Se
- First lifetime measured in the very exotic ^{84}Ge
- Unexpected enhancement of collectivity in ^{84}Ge

Sudden rise of collectivity after the N=50 shell closure

… in contradiction with shell model calculation

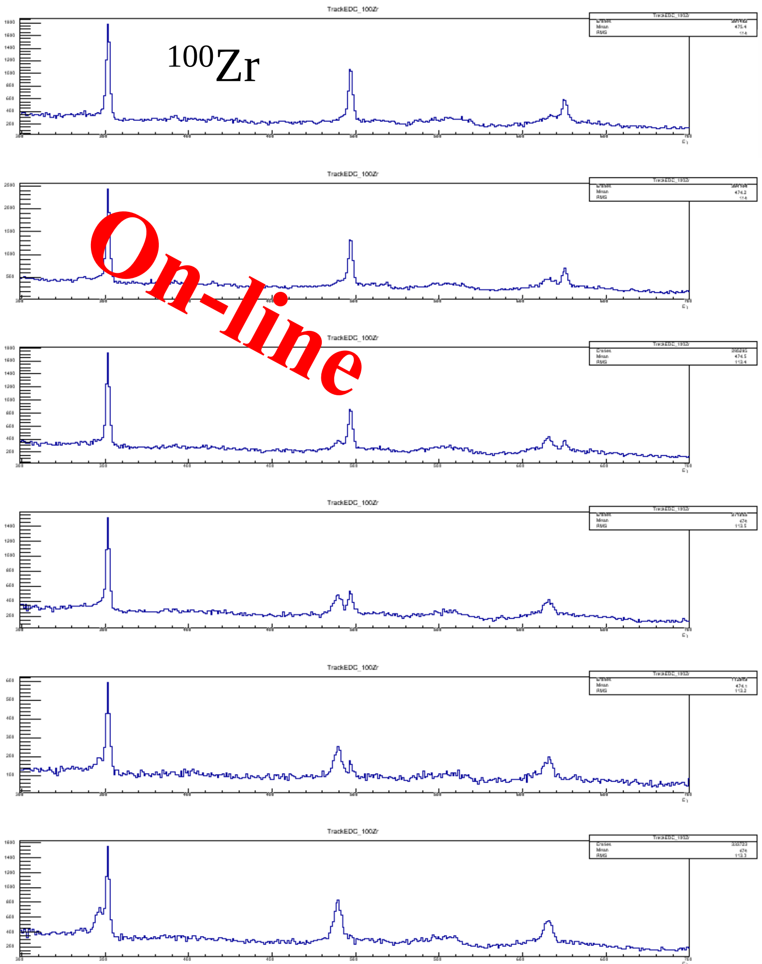
C. Delafosse et al., submitted to Phys. Rev. Lett.

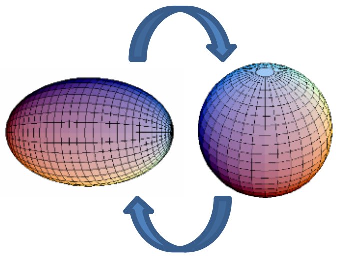
Shape evolution in fission fragments in the A~100 region

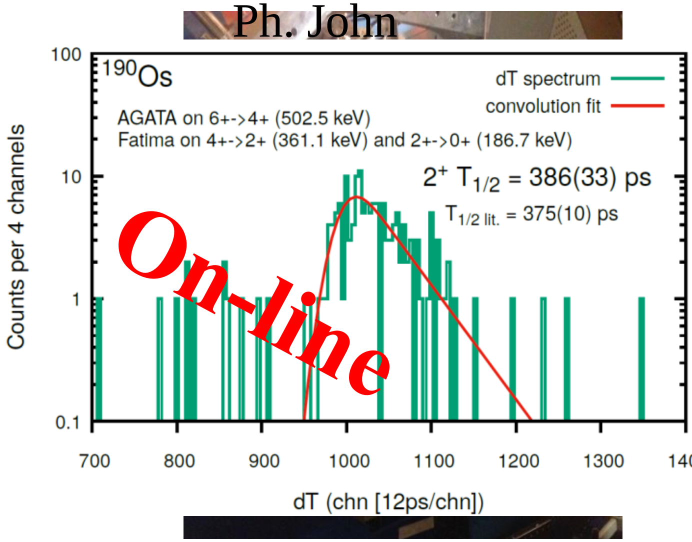
AGATA-VAMOS and a plunger + FATIMA for lifetime measurements using the $^{9}Be(^{238}U,FF)$ reaction

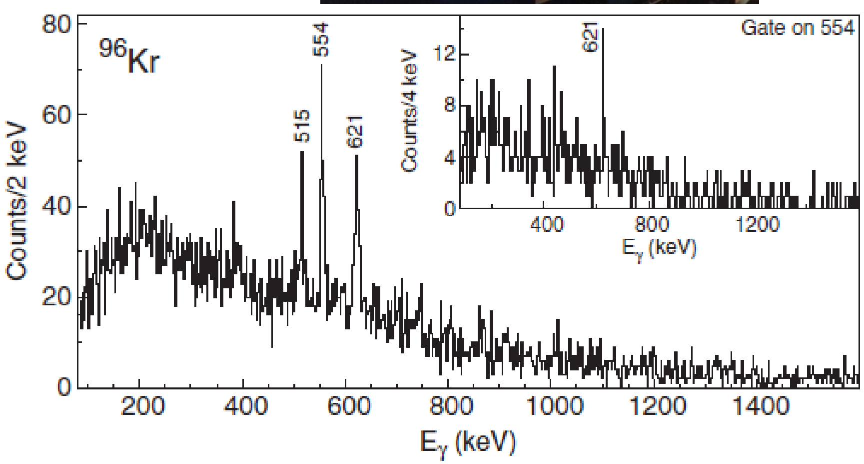
W. Korten, A. Görgen et al

Ph. John







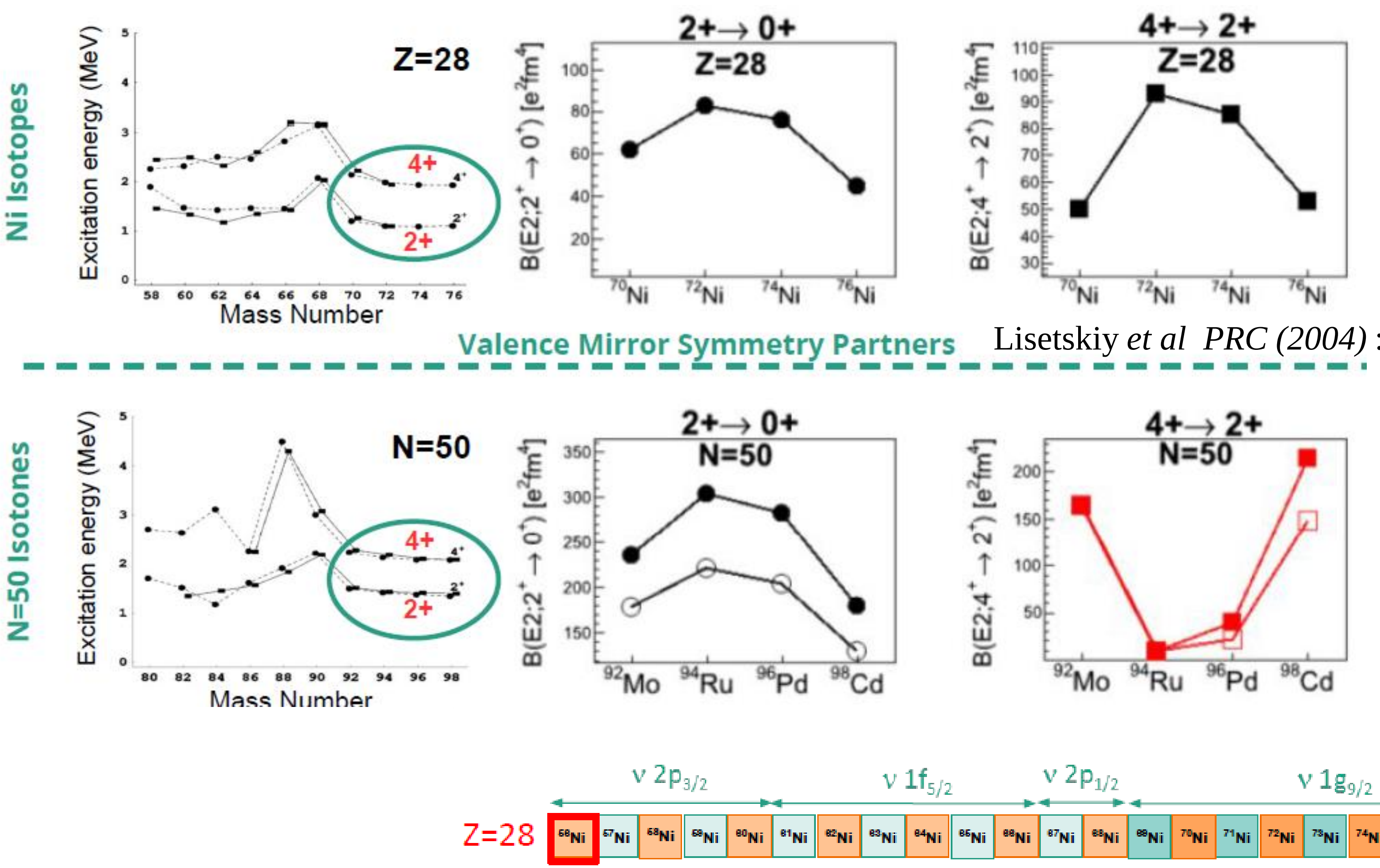


High resolution spectroscopy of ^{96}Kr

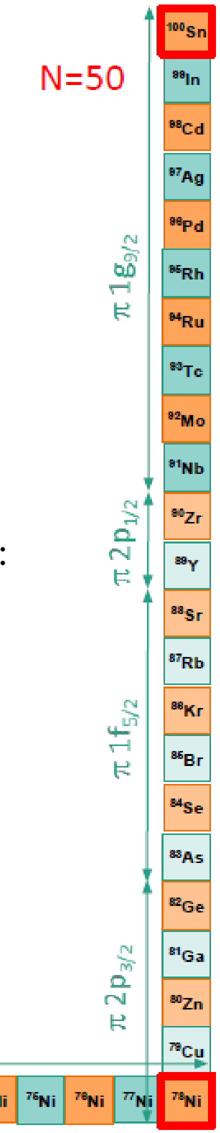
J. Dudouet et al. Phys. Rev. Lett. 118, 162501 (2017)

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.

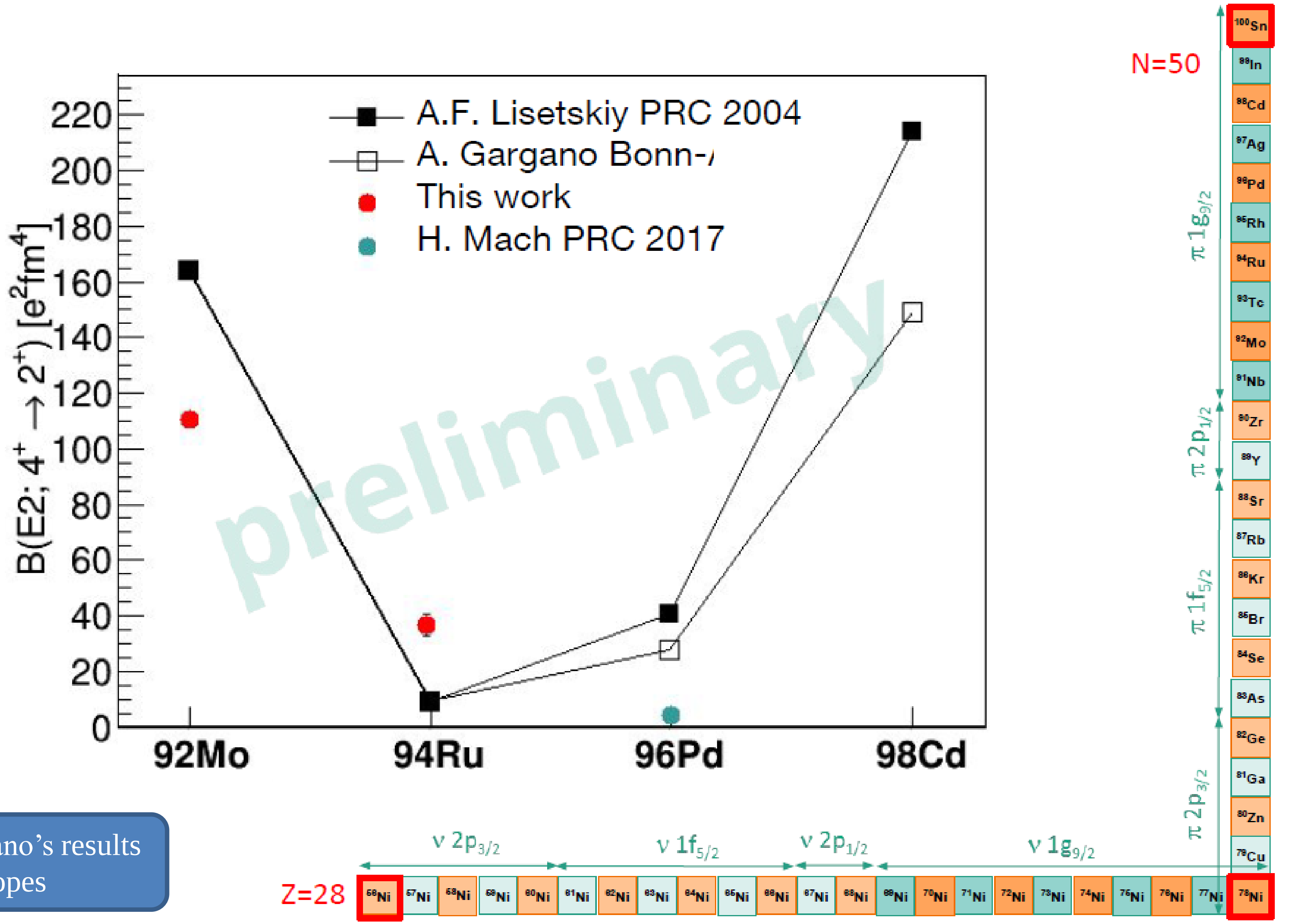


Lisetskiy *et al* *PRC (2004)* :



courtesy of R. Perez Vidal

Shell evolution around ^{100}Sn



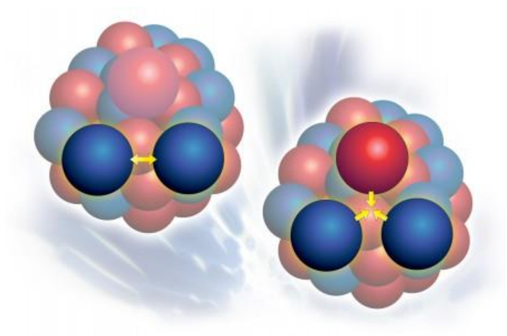
See also M. Siciliano's results on Sn isotopes

courtesy of R. Perez Vidal

Lifetime in n-rich O and C

S. Leoni, B. Fornal, M. Ciemala et al.,

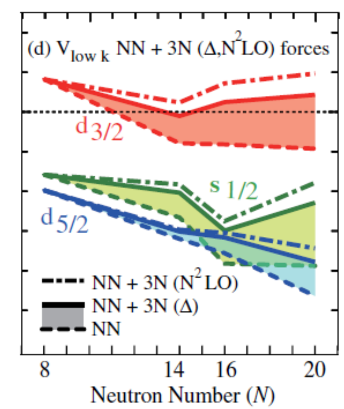
Lifetime measurement in the non-yrast excited states of neutron rich C and O isotopes.
Branching ratio and E2/M1 using the PARIS LaBr3 array

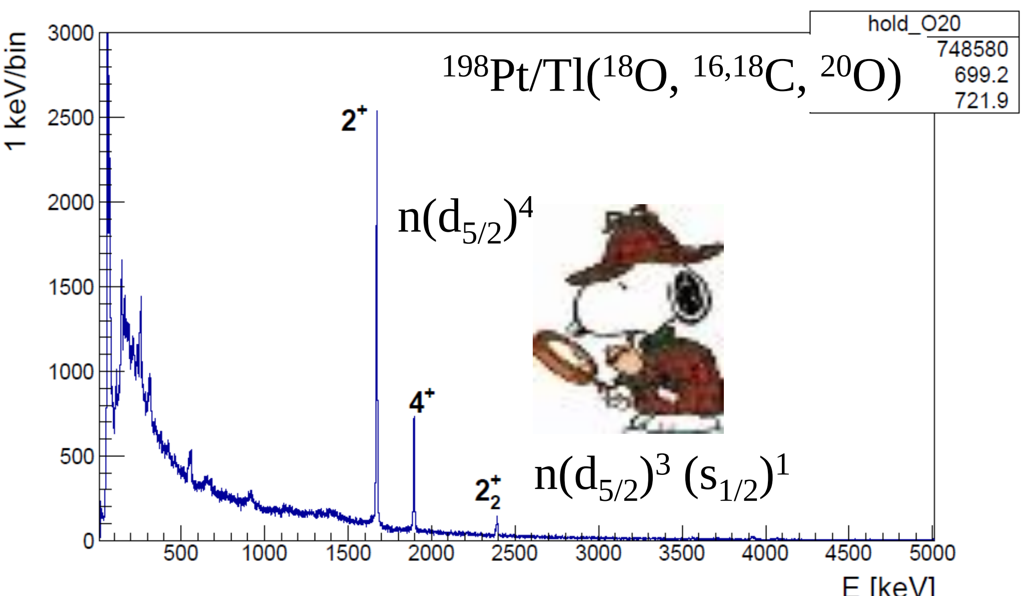


The 2^+_2 state corresponds to a neutron $(d_{5/2})^3(s_{1/2})^1$ configuration

C. R. Hoffmanu et al .PRC **85**, 054318 (2012)

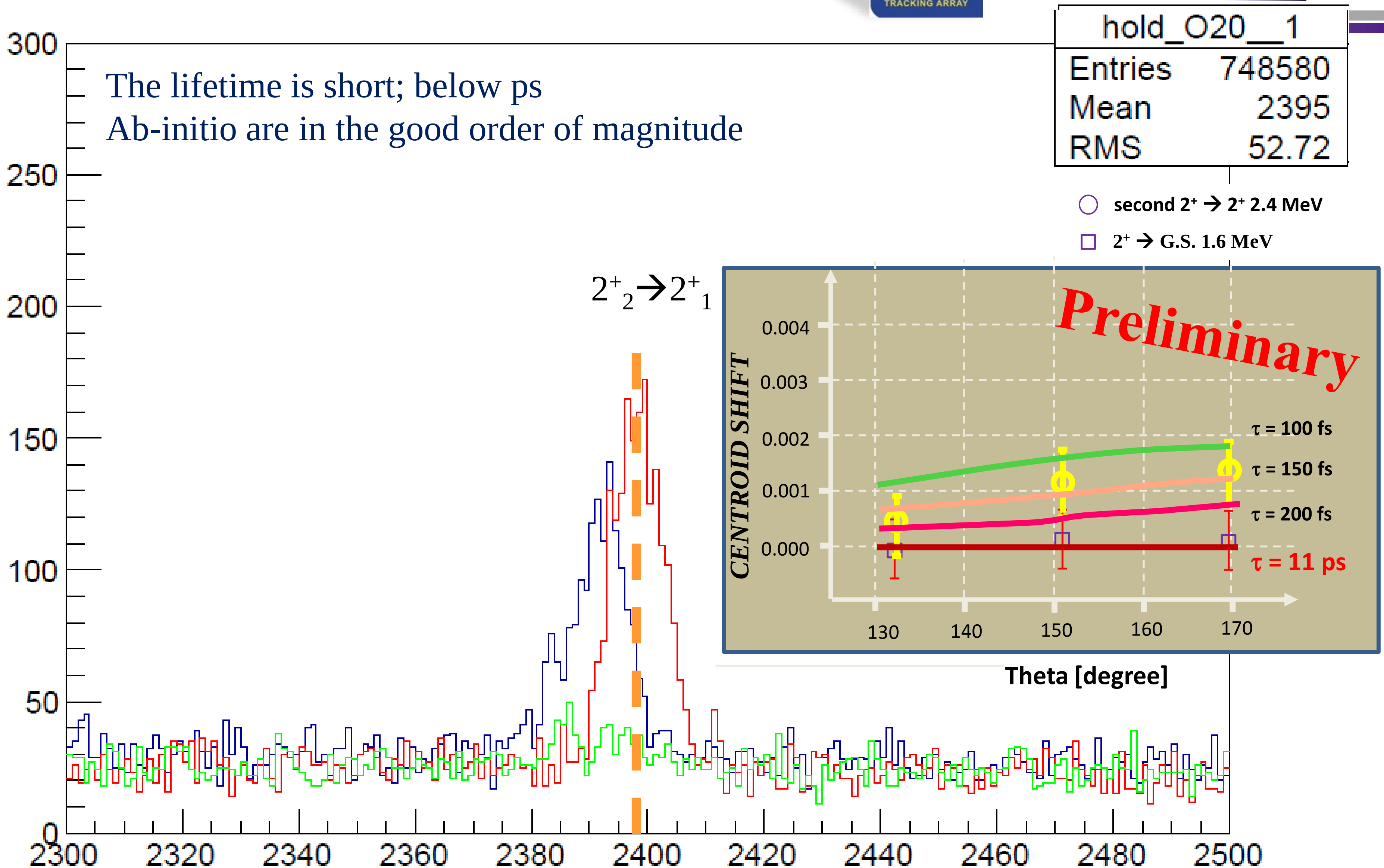
T. Otsuka PRL 105, 032501 (2010)



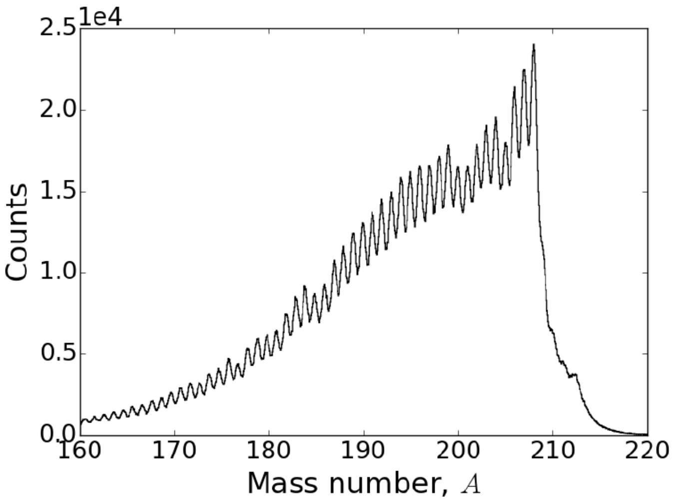


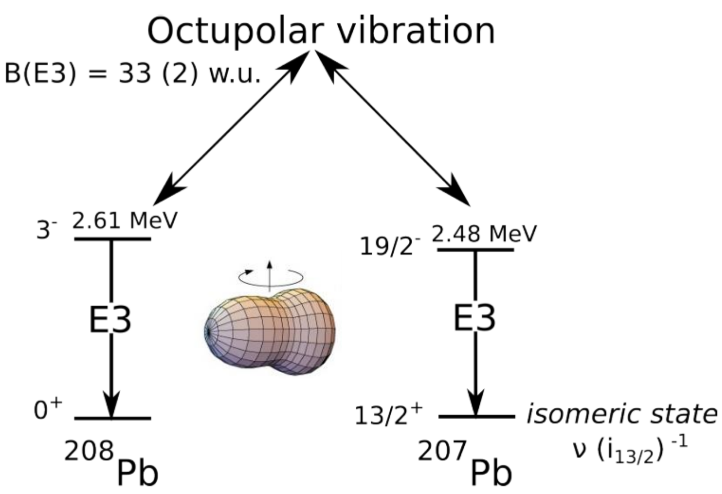
Nucleus	Excited state	Interactions: lifetime τ [ps] (*ab initio* NN)	lifetime τ [ps] (*ab initio* NN+ NNN)	mixing ratio δ (E2/M1) for $2^+_2 \rightarrow 2^+_1$ (*ab initio* NN)	mixing ratio δ (E2/M1) for $2^+_2 \rightarrow 2^+_1$ (*ab initio* NN+NNN)	Experiment τ [ps]
^{16}C	2^+_1	24	24			11.4(10) - 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**	-

Performances of AGATA



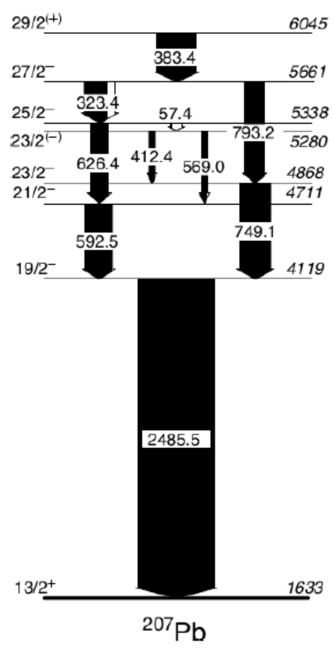
Shell evolution around ^{208}Pb

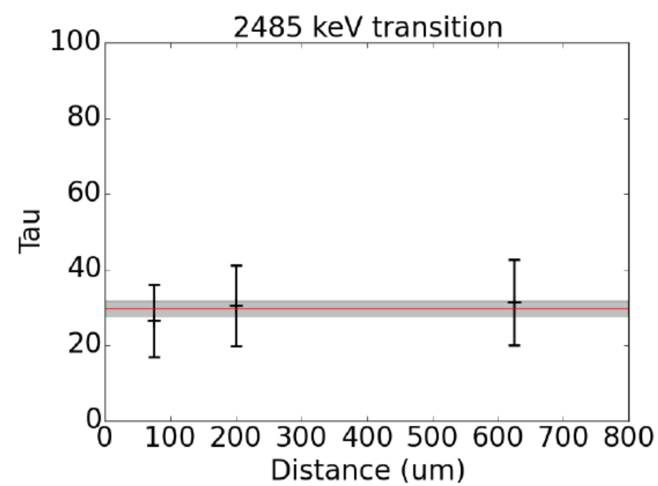




Study of the two-phonon vibrational states in the ^{208}Pb region

Case of the ^{207}Pb $\nu(i_{13/2})^{-1}$ state band structure



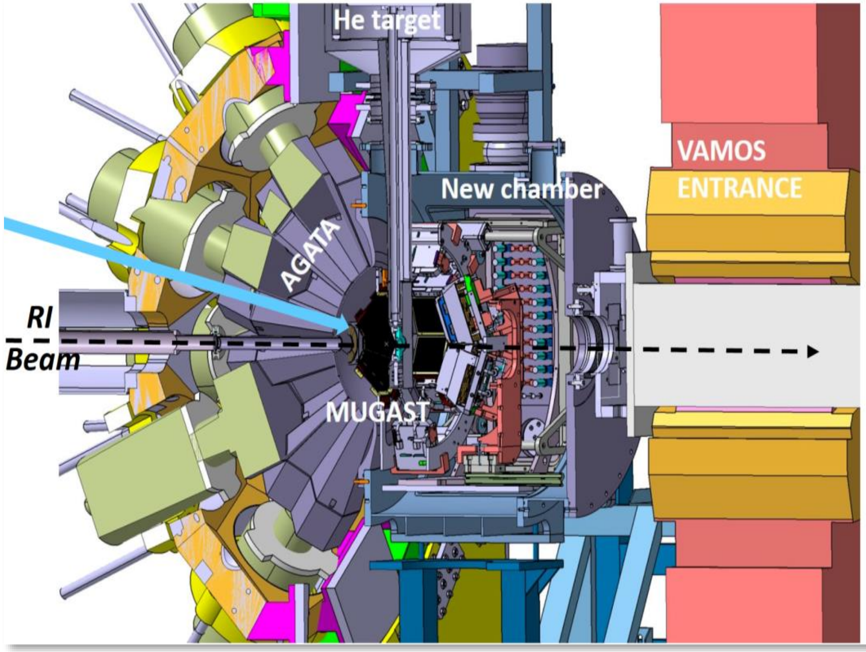


D. Ralet in preparation

D. Ralet et al., Phys.Scr. 92, 054004 (2017)

MUGAST campaign 2019

Nucleons transfer spectroscopy using the 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), (^{3}He,n)
n-p pairing, clusterization

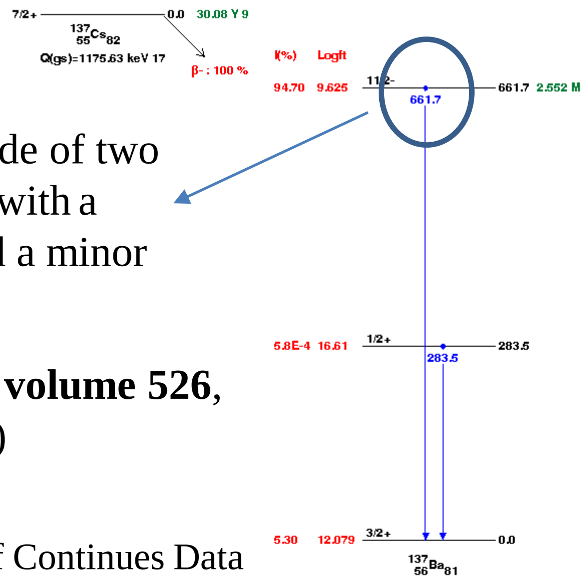
Lifetime measurement after single nucleon transfer

2018 call for proposal
PAC meeting in November
Start of the campaign in April 2019

Campaign manager : M. Assié (IPNO)

Double Gamma decay

D. Brugnara, A. Goasduff, JJ Vailente-Dobon et al.



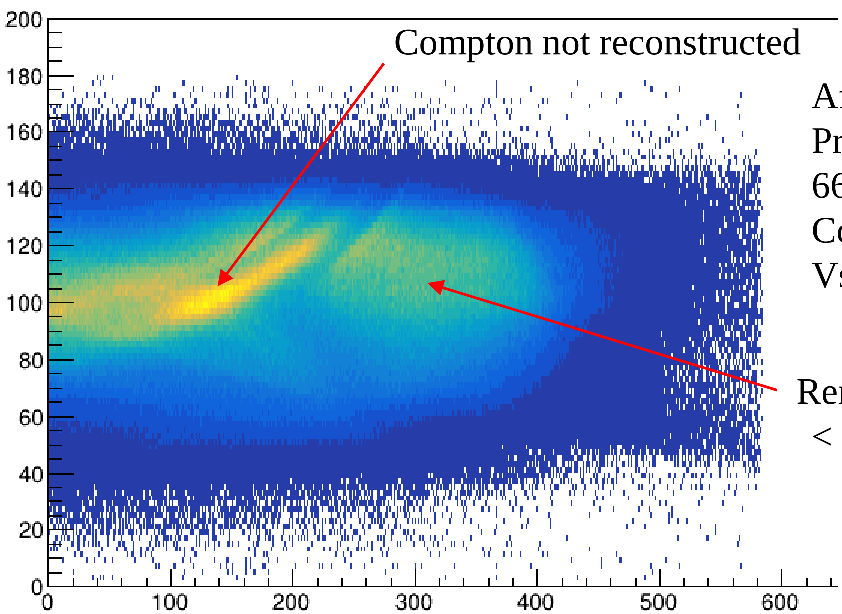
Can decay as a cascade of two gamma (P ∞ 2 10^{-6}) with a dominant M2-E2 and a minor E3-M1 contribution

C. Walz et al., *Nature* **volume 526**, pages 406–409 (2015)

The main point is to discriminate the real double gamma event candidates on top of the "background" of the Compton scattering.

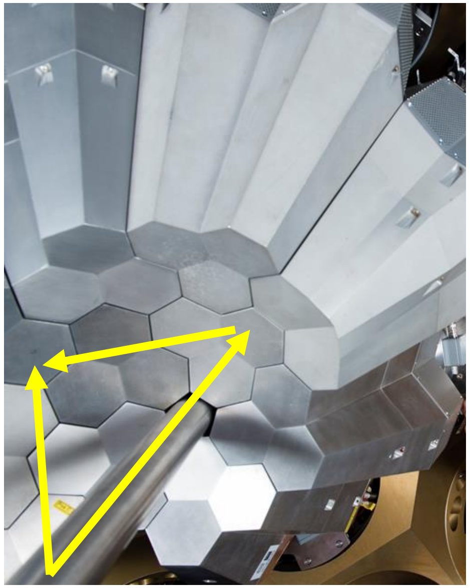
"Tracking" should be able to reconstruct the Compton scattering and leave only candidate for the double events … Proof of principle ?

30-31 May 2018 : 49h of Continues Data



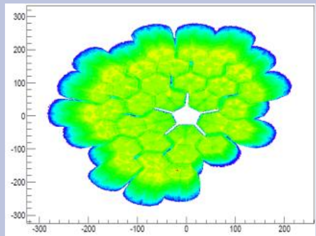
After Tracking – OFT Std
Prompt Track1+Track2 =
661 ± 1.5 keV, nbTrack=2
Compton Angle (Track1,Track2)
Vs Diff (ETrack1, ETrack2)

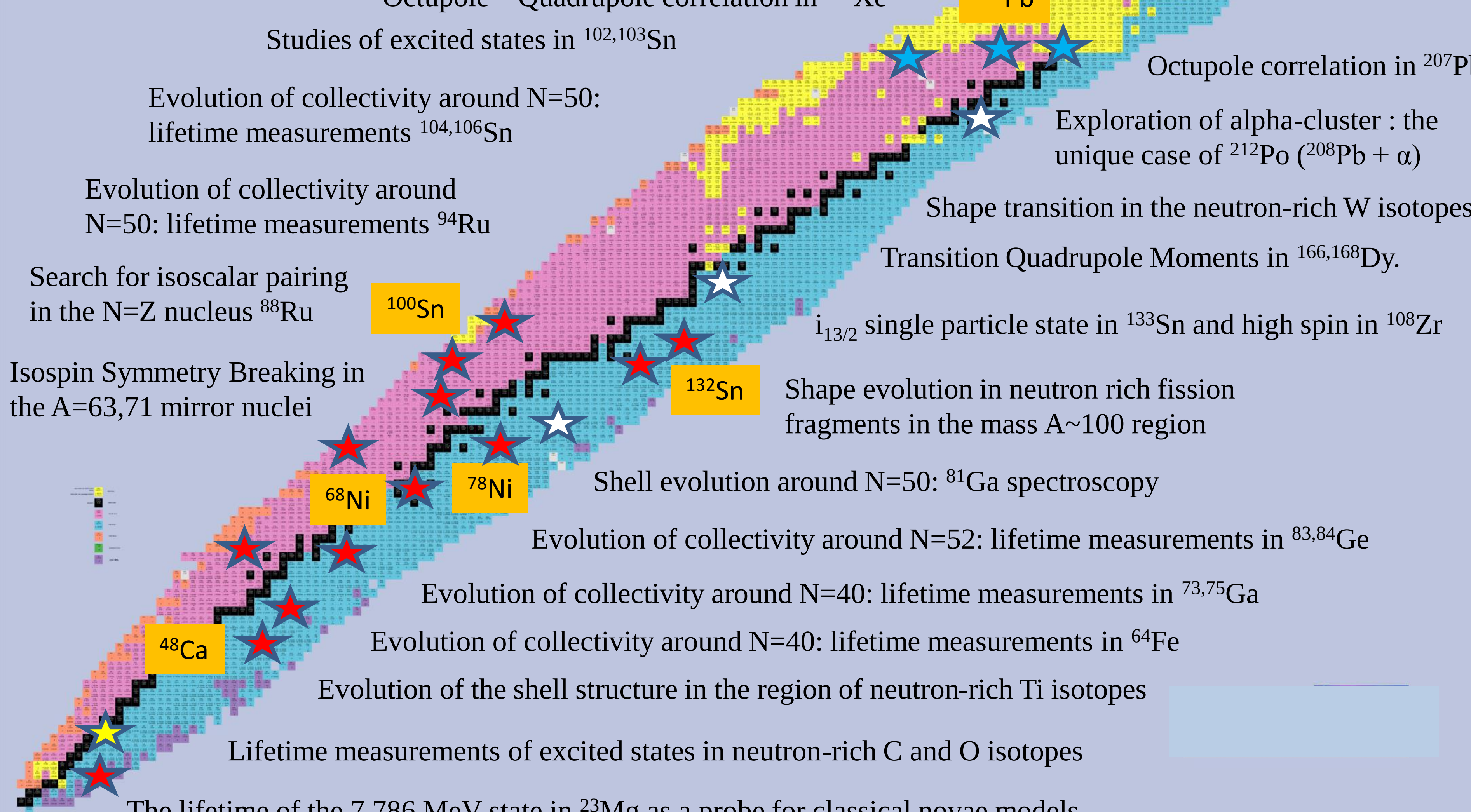
Remain to be understood in details
< 0.007% of events



^{137}Cs

Experiments performed in 2015-2018 at GANIL with AGATA





Conclusion

- AGATA is operated since 2014 at GANIL and 22 experiments have been performed
  - 4 Papers published (2015-2016 data)
  - 1 Submitted (2015 data)
  - 5 Papers in preparation (2015, 2016 and 2017 data)
  - 1Technical papers submitted
  - 1Technical papers in preparation
  - 16 Experiments under analysis (2016-2018)
  - 3 PhD defended in 2017 and 7 in preparation using GANIL data

- The number of detectors is increasing and stability of the system is improved year after year

- Successful NEDA-DIAMANT-AGATA campaign in 2018

- Many results are coming all along the nuclear chart for many different physics topics

- Publications are important for GANIL and AGATA

- Many thanks to all AGATA collaborators !